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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : A63F	A2	(11) International Publication Number: WO 99/17850 (43) International Publication Date: 15 April 1999 (15.04.99)

(21) International Application Number: PCT/US98/19905

(22) International Filing Date: 23 September 1998 (23.09.98)

(30) Priority Data:
08/935,762 23 September 1997 (23.09.97) US

(71)(72) Applicants and Inventors: THORNER, Craig [US/US]; 16 Nantucket Court, Howell, NJ 07731 (US). NEILMAN, Paul [US/US]; 1240 Rhus Street, San Mateo, CA 94402 (US).

(74) Common Representative: THORNER, Craig; 16 Nantucket Court, Howell, NJ 07731 (US).

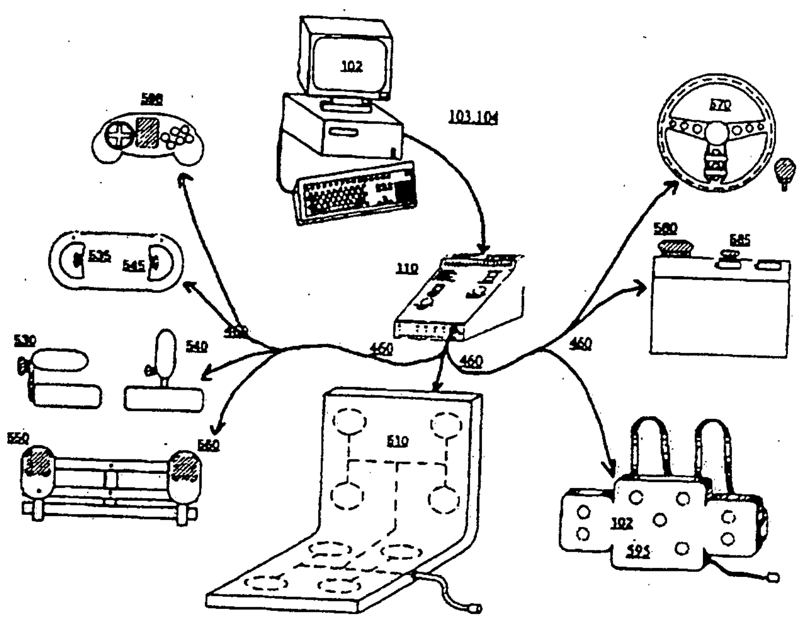
(81) Designated States: CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

Published
Without international search report and to be republished upon receipt of that report.

(54) Title: A UNIVERSAL TACTILE FEEDBACK SYSTEM FOR COMPUTER VIDEO GAMES AND SIMULATIONS

(57) Abstract

A universal tactile feedback system for comptuer and video game systems is disclosed which provides real time tactile feedback to enhance a user's experience while interacting with a computer/video game or simulation. The system includes a microcontroller based circuit that can operate in either a host-independent or a host-dependent mode. The host-independent mode is responsive to an audio signal which is typically generated by a computer or video game system while it is executing a game or simulation. In real time, the audio signal is pre-processed, digitally sampled, and digitally post-processed. The digital post-processing utilizes an algorithm with reprogrammable parameters that can be uniquely set for any given game or simulation. After the audio signal is processed, the results are used to generate multiple independent control signals for multiple independent tactile sensation generators. Each control signal causes a tactile sensation generator to produce tactile sensations corresponding



to the events occuring within the game or simulation. Alternatively, the host dependent mode is directly responsive to control commands specifically generated by a computer or video game system while it is executing a game or simulation. These control commands are digitally processed and then used to generate multiple independent control signals for multiple independent tactile sensation gnerators. All reconfigurable parameters controlling the operation of the system are reprogrammable in real time by sending a dynamic batch communication to the microcontroller via any typical digital I/O port. This allows the system to be reconfigured during use without substantially interrupting the real time function of the system. The system's tactile sensation generators include independent groups of one or more actuators, e.g., electric motors or solenoids, that are embedded within or attached to various devices that can be connected to the system.

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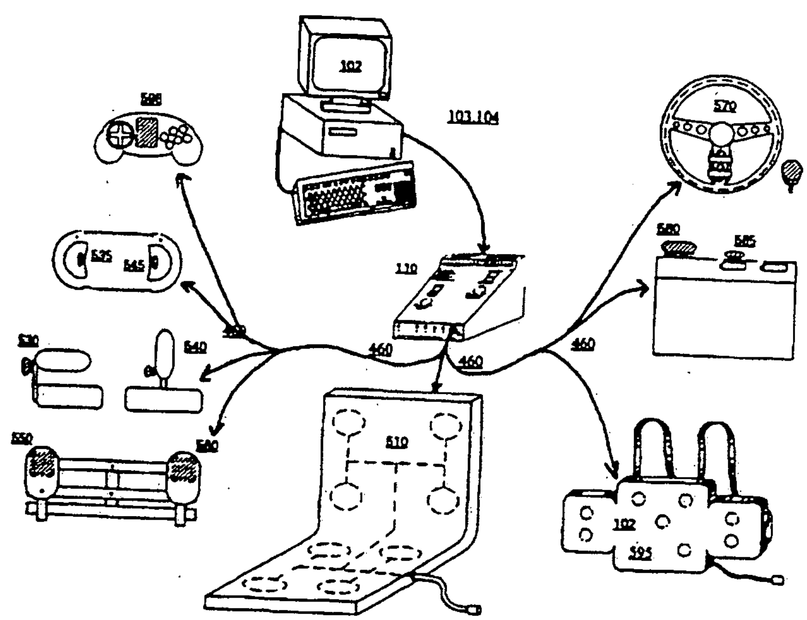
Published
With international search report.

(88) Date of publication of the international search report: 17 June 1999 (17.06.99)

(54) Title: A UNIVERSAL TACTILE FEEDBACK SYSTEM FOR COMPUTER VIDEO GAMES AND SIMULATIONS

(57) Abstract

A universal tactile feedback system for comptuer and video game systems which provides real time tactile feedback. The system includes a microcontroller based circuit that can operate in either a host-independent or a host-dependent mode. The host-independent mode is responsive to an audio signal which is typically generated by a computer while it is executing a game. The digital post-processing utilizes an algorithm with reprogrammable parameters that can be uniquely set for any given game or simulation. After the audio signal is processed, the results are used to generate multiple independent control signals for multiple independent tactile sensation generators (510, 520, 530, 540, 535, 545, 550, 560, 570, 575, 585, 595 and 598). Alternatively, the host-dependent mode is directly responsive to control commands generated by a computer while it is executing a game. All reconfigurable parameters are reprogrammable in real time by sending a communication to the controller (110) via any typical digital I/O port. The system's tactile sensation generators include independent groups of one or more actuators that are embedded within or attached to various devices.



A UNIVERSAL TACTILE FEEDBACK SYSTEM FOR COMPUTER VIDEO GAMES AND SIMULATIONS

This application derives its priority from U.S. Patent Application Serial Number 08/935,762 filed on 9/23/97.

FIELD OF THE INVENTION

This invention relates to a tactile feedback system for computer and video game systems and, more particularly, to a universal tactile feedback system for computer and video game systems which provides real time tactile feedback to enhance a user's experience while interacting with a computer/video game or simulation.

BACKGROUND OF THE DISCLOSURE

With the advent of low cost microprocessors and the explosive growth of the PC industry, electronic gaming has proliferated at a blinding rate. Games and simulations are now executed, in homes and arcades, on a vast array of available hardware platforms, where each hardware platform yields its own unique combination of complexity, and fidelity, and cost. Depending on a given hardware implementation, game players may have many different types of control input devices at their disposal that are used to interact with a game or simulation. For example, driving games and simulations may use any combination of control input devices such as steering wheels, gear shifters, and gas/brake/clutch pedal units. Flight games and simulations may use any combination of control input devices such as throttles, weapons controllers, joysticks, rudder pedals, and flight yolks. First person perspective action games may use any combination of joystick, mouse, or 3D control. In most cases, a person playing a game or simulation is sitting in a seat of some kind while interacting with the hardware control input devices.

In order for tactile sensation to be effectively implemented by a modern electronic gaming system, where there are so many inconsistencies between various hardware systems and their software applications, an entirely new approach is necessary. In order to be most effective, a gaming or simulation system must be able to provide the illusion that all of the available disparate control input devices that control a given simulation are each part of a unified whole, and that they are not independent, physically disconnected devices. This is necessary to suspend the disbelief of the person who is interacting with the game or simulation system.

Due to the current and future countless implementations of computer based video game and simulation systems, and due to the continually expanding library of game and simulation applications that can be executed on such systems, a need exists in the art for a truly universal tactile feedback system that can function without regard to the specific apparatus, implementation, or application of any given system. Furthermore, a need exists in the art for a universal system that can accommodate currently existing and future control input devices, via simple and inexpensive tactile feedback actuators, that can be readily connected to or embedded within said devices, such that these disparate devices become part of a unified whole. Additionally, a need exists in the art for a universal system that will function both with and without support by the host gaming apparatus, achieving said functionality by implementing both a reprogrammable audio analysis function, and /or a direct digital control function. Moreover, a need exists in the art for a tactile feedback seating unit, that is not based on a low frequency speaker system, such that vehicle based games and simulations can be more realistically rendered, both with and without support by the host gaming apparatus. Furthermore, a need exists in the art for a vest-based tactile sensation generator, such that both open-body games and vehicle based games can be more realistically rendered, both with and without support by the host gaming apparatus. Finally, a need exists in the art for a universal tactile feedback system, such that the complete system is versatile, inexpensive, reliable, lightweight, quiet, reconfigurable, reprogrammable, and expandable.

Accordingly, it is a primary objective of the present invention to introduce a tactile feedback seating unit that can produce tactile feedback within a seat, that is not based upon a low frequency speaker system, that can function via host-independent digital audio analysis and/or host-dependent direct digital control, the digital signal not necessarily being specific to the actuators in the seat, but rather a general control signal for a distributed system, in order to represent tactile sensations occurring in real time within a computer generated game or simulation, such that the person sitting in the seat feels this representation, and the tactile feedback provided by such a system further enhances the believability of the simulation. It is an additional primary objective of the present invention to implement the tactile feedback seating unit as a self contained unit, where a plurality of tactile feedback actuators are embedded inside a semi-rigid sealed foam cushion, such that the unit is portable, lightweight and quiet, and can fit in almost any chair and function with almost any application.

FIG. 10 depicts a flow chart of a method for generating control signals for tactile sensation generators under a host independent and host dependent modes of operation;

FIG. 11 is a flow chart for the method of post-processing the audio signals;

FIG. 12 is flow chart of a method for processing raw audio signals with a plurality of audio analysis parameters;

FIG. 13 is a flow chart of a method of post-processing the direct control signal;

FIG. 14 is a flow chart of a method for generating control signals for tactile sensation generators;

FIG. 15 is a block diagram illustrating the relationship between the digital control signal table, device specific power output parameters table and the PWM control signal table;

FIG. 16 is a flow chart of the batch data transmission method;

FIG. 17 is a flow chart of a "no user intervention" method to trigger the batch data transmission method;

FIG. 18 is a flow chart of a "user intervention" method to trigger the batch data transmission method;

FIG. 19 is a flow chart of a host-independent audio analysis calibration method;

FIG. 20 is a flow chart that illustrates a method of activating LEDs via a multiplexing method;

FIG. 21 is a flow chart that illustrates a method of reading hardware switches via a multiplexing method;

FIG. 22 is a circuit diagram of the LED display of FIG. 23;

FIG. 23 is an illustration of a LED display with the circuit of FIG. 22;

FIG. 24 is an illustration of the user input switches on the tactile feedback controller;

FIG. 25 is a functional block diagram of both the multiple independent PWM control signal generation component and the PWM outputs of the present system;

FIG. 26A depicts the first of four common control input device hardware suites;

FIG. 26B depicts a second of four control input device hardware suites;

FIG. 26C depicts a third of four control input device hardware suites;

FIG. 26D depicts a fourth of four common control input device hardware suites;

FIG. 27A illustrates a tactile feedback seating unit with six actuators;

FIG. 27B illustrates the tactile sensation actuators that are embedded within the tactile feedback seating unit;

FIG. 27C illustrates a tactile feedback seating unit with eight actuators;

FIG. 28A is a diagram of a chest tactile sensation generator;

FIG. 28B is a diagram of a chest tactile sensation generator;

FIG. 28C is a diagram of a chest tactile sensation generator;

FIG. 29A illustrates a DC motor which has an offset weight on its shaft, in a side view;

FIG. 29B illustrates a DC motor which has an offset weight on its shaft, in a front view;

FIG. 29C illustrates a DC motor in a housing, in a side view;

FIG. 29D illustrates a DC motor in a housing, in a front view;

FIG. 29E illustrates a solenoid in a housing, in a side view;

FIG. 30A illustrates the housing having an attachment means of a two-sided adhesive strip;

FIG. 30B illustrates the housing having an attachment means of two corresponding halves of hook and loop fasteners;

FIG. 30C illustrates a hook and loop fastening means affected upon a strap;

FIG. 31A is a rear side view of a center-mounted throttle;

FIG. 31B is a top down view of a center-mounted throttle;

FIG. 31C depicts a throttle tactile sensation generator;

FIG. 31D is a top down view of the apparatus of FIG. 31C;

FIG. 31E is a rear side view of a side-mounted throttle;

FIG. 31F is a top down view of a side-mounted throttle;

FIG. 31G depicts a throttle tactile sensation generator;

FIG. 31H is a top down view of the apparatus of FIG. 31G;

FIG. 32A is a rear side view of a joystick;

FIG. 32B is a top down view of a joystick;

FIG. 32C is a rear side view of a joystick, with a tactile sensation actuator attached to its shaft;

DETAILED DESCRIPTION

FIG. 1 depicts a high level block diagram of a tactile feedback system 100 interfacing with a computer system or video game console 102 (hereinafter host computer). The host computer 102 is connected to the tactile feedback system 100 by electrical connections 103 and 104 which may carry analog or digital signals respectively. In fact, signals from the host computer can be passed to the tactile feedback system using other types of communication channels 106, e.g., channels that employ infrared radiation, radio wave or sound wave. If these communication channels are used, then the corresponding receivers must be implemented on the tactile feedback system, e.g., RF receiver, IR receiver or a microphone.

Thus, it should be understood that the configuration of having the host computer 102 coupled to the tactile feedback system 100 is only illustrative and the present invention is not so limited. Namely, the host computer 102 can be implemented as any device that is capable of sending the necessary control signals, such that the tactile feedback system is capable of operating one or more tactile sensation generators (e.g., a gaming console with integrated tactile feedback controller functionality).

The tactile feedback system 100 comprises a tactile feedback controller 110 and one or more tactile sensation generators 120. In the preferred embodiment, the tactile feedback controller 110 is connected by power distribution cables 116 to multiple independent tactile sensation generators 120. However, the present invention can be modified such that only control signals are forwarded to the tactile sensation generators, where each generator is able to be activated under its own power source.

The tactile feedback controller 110 comprises a host independent portion 112 and a host dependent portion 114. Namely, the host-independent portion allows the tactile feedback controller 110 to interpret the audio signals from a video game to generate the control signals for the tactile sensation generators. Under this mode of operation, the tactile feedback controller is able to use the audio signals to properly decipher the actions of the video game, independent of any control signals from the video game.

In contrast, the host-dependent portion allows the tactile feedback controller 110 to receive and process the control signals from a host computer 102 to generate the control signals for the tactile sensation generators. Namely, the control signals from the host computer 102 is designed specifically for the tactile feedback system.

In the preferred embodiment, electrical connection 103 represents the audio cable (stereo or mono) that carries the analog audio signal produced by the host computer 102. More specifically, the host computer 102 has one of its audio output ports, e.g., an amplified or line-level 1/8 inch stereo output connector, connected via line 103 to an input port 118 of the tactile feedback controller 110.

Similarly, electrical connection 104 represents a cable that carries the digital signal produced by the host computer 102 to an input port 119 of the tactile feedback controller 110. In this preferred embodiment, the digital cable 104 is a parallel cable, e.g., a DB25 to DB25 "straight through" male to male cable. However, it should be understood that the present invention can be implemented with any type of digital cables, port configurations and various other transmission protocols (such as RS-232 DB9 serial or USB universal serial bus, PCMCIA card connector and cable, coaxial cable, and the like).

Furthermore, a pass through port 117 is coupled to port 119 to allow the signals carried on the electrical connection 104 to pass through port 119. This pass through port allows multiple tactile feedback controllers 110 to be daisy chained to support additional tactile sensation generators. This pass through port also serves to pass non-tactile sensation related signals to other peripherals, e.g., a printer.

In the preferred embodiment, twelve (12) pins on the electrical connection 104 are employed to communicate with the tactile feedback controller 110. Namely, the present invention employs a 12-bit bus for communication with a communication format having a 4-bit control word and an 8-bit data word. Throughout this disclosure, the physical locations for the 4-bit control word and 8-bit data word on line 104 are referred to as PORT A and PORT B, respectively.

It should be understood that although the present invention employs a 12-bit bus for communication, buses of any size can be implemented. Generally, the selection of a communication protocol and bus size is governed by the requirements of a particular application. For example, a more powerful microcontroller may have sufficient I/O pins to allow a communication format greater than 12 bits.

Furthermore, bi-directional communication can also be implemented between the host computer 102 and the tactile feedback controller 110. Such bi-directional communication would allow the tactile feedback controller 110 the ability to transmit internal status, verification and operating data to the host computer system 102.

TTL circuit lines to the transistor switch circuits 350, to drive one or more tactile sensation generators 120 that are connected to the tactile feedback controller 110.

Additionally, a display 370 (20 LEDs) is coupled to the microcontroller 320 for providing a visual aid to a user who is performing a configuration function or who is simply monitoring the status of the tactile feedback controller 110. More specifically, the display allows the user to see the internal activity of the tactile feedback controller 110, by activating the LEDs in a manner that illustrates the status of many different types of information. This information may include real time audio sampling data, real time audio analysis data, direct digital signal control data, and various parameters that control aspects of the tactile feedback generated by the tactile feedback controller 110. Although the preferred embodiment has implemented this display as a horizontal strip of 20 rectangular LEDs, this display can be implemented in many different ways or not at all.

For example, an alphanumeric liquid crystal display (LCD) having two (2) display lines of 12 characters can be used to display a parameter name on the first LCD display line, and the parameter's numerical value on the second LCD display line, followed by some unit label (e.g., seconds, percent, amplification, reduction, and the like, as necessary). Furthermore, simple messages such as "YES", "NO", and other words can also be displayed on such an alphanumeric display, when appropriate.

Finally, tactile feedback controller 110 further incorporates a plurality of switches 360, which include a mode select switch, a function select switch, and a rotary encoder switch. The functions of these switches are described in greater detail below. Although the present invention utilizes three hardware switches, those skilled in the art will realized that any number of switches, or no switches at all, can be implemented in the present invention.

FIG. 4 depicts a block diagram of the audio signal preprocessing section 310. The audio signal preprocessing section 310 comprises a front end circuit 410, a variable gain preamplifier 420, and three separate audio filters/buffers 430-450.

More specifically, a stereo audio signal from the host computer 102 enters the front-end circuit 410 within which the stereo audio signal is combined into a composite signal. Namely, host computer 102 sends an audio signal via audio cable 103, comprising a left audio channel and a right audio channel. The front end circuit 410 contains a mixer for combining both channels of a stereophonic audio signal to form a composite audio signal, a high pass filter for limiting noise that is below the audio band, e.g., lower than 20 Hz, and a diode signal limiter for limiting (clipping) the amplitude of the input signal to protect the audio signal preprocessing section 310 from overly powerful audio signal inputs.
A detail circuit diagram of the front end circuit 410 is depicted in FIG. 5.

The output from the front end circuit 410 then enters a variable gain preamplifier 420. The variable gain preamplifier 420 establishes the dynamic range of the analog audio signal preprocessing section 310. Namely, the tactile feedback controller 110 provides the user with a calibration knob that varies the resistance provided by a potentiometer, which, in turn, determines the gain of the variable gain preamplifier 420. For example, if the gain of the variable gain preamplifier 420 is set too high, the audio signal has a tendency to saturate and, consequently, the usefulness of the audio signal is compromised. Alternatively, if the gain of the variable gain preamplifier 420 is set too low, the audio signal does not have sufficient dynamic range to provide useful data to the host-independent section 112. A detail circuit diagram of the variable gain preamplifier 420 is depicted in FIG. 6.

FIG. 6 illustrates a switch SW5 to address audio output signal of different strengths. Namely, a host computer 102 may typically produce an audio signal in two different types of audio output signal strengths, i.e., amplified "speaker" outputs and non-amplified "line level" outputs. Most audio output cards allow a computer user to select a signal strength that is optimal for his or her audio equipment. However, older audio output cards often provided only amplified audio output signal strength on a single connector. Amplified "speaker" audio output typically provides 4 watts of amplification at 8 ohms resistance. In cases where the host computer 102 only has one audio output jack, the single output can be split via a readily available Y-type adapter that will provide two output jacks from the single pre-existing jack. Thus, the Y-adapter provides one connector for the user's speakers, and a second connector for the user to couple the host computer to the tactile feedback controller 110.

The second type of audio output signal strength is non-amplified "line level" audio output, which is commonly used by stereo equipment. This audio output signal strength is typically meant for an external stereo amplifier, such that the audio output of the host computer 102 can be broadcast from the user's home stereo system. Similarly, the line level output jack can also be split, when necessary, with a Y-type adapter.

is depressed by the user during the power on reset sequence. In fact, the stored demonstration in the ROM can also be used as a manufacturing test to verify newly manufactured tactile feedback controllers. By implementing a predetermined sequence that is designed to exercise all features of the tactile feedback controller and to activate every available tactile sensation generators, the demonstration sequence can be used to detect malfunction. The demonstration lasts approximately 90 seconds.

Returning to step 1030, method 1000 queries whether a configuration command is detected. More specifically, in the present invention, configuration commands are provided in the form of a batch data transmission. Batch data transmissions carry data that allows various operational parameters of the system to be reconfigured in real time. These batch data transmissions begin with a multi-stage trigger (code), which alternatively strobes back and forth between two predetermined values. If the data present on the input ports of the tactile feedback controller 110 is identified as a trigger strobe for a batch data transmission, then method 1000 proceeds to step 1035 where the configuration commands/data within the batch data transmission are executed. Examples of functions that can be executed at this step include: 1) changing display modes of various internal variables on the LED display (See Appendix A for a list of such display modes), 2) setting various tactile sensation generator power output parameters, and 3) setting any of the audio postprocessing parameters at discussed below in step 1065. Once all the configuration commands/data are serviced by the tactile feedback controller 110, method 1000 proceeds to step 1040.

In step 1040, method 1000 queries whether host dependent mode is selected. If the query is negatively answered, then method 1000 proceeds to step 1065, where audio signal postprocessing is executed. If the query is affirmatively answered, then method 1000 proceeds to step 1050, where method 1000 determines if digital control is active.

Namely, if the tactile feedback system is set in the host-independent audio analysis mode, method 1000 executes the digital audio post processing procedure. If the tactile feedback system is not set in the host-independent audio analysis mode, then the system is in the host-dependent direct control mode by default.

In step 1050, method 1000 queries whether digital control has been previously activated since the last power on reset. Namely, method 1000 determines if a specific start code has been received at PORT A and PORT B. The specific start code indicates that a software application on the host computer 102 is attempting to send digital signals to the tactile feedback controller 110. More importantly, the initial reception of this start code would have initialized the host dependent section 114 of the tactile feedback controller 110. Such initialization places the host dependent section 114 in condition to receive control signals from the host computer. This start code is employed to keep the direct digital control mode from erroneously reacting to data on the parallel printer port bus that may not be intended for the tactile feedback controller 110. This may occur if devices other than tactile feedback controllers 110 are daisy chained along the parallel bus, such as printers, tape back up drives, portable SCSI devices, and so on. If the query is affirmatively answered, i.e., direct digital control was previously activated, method 1000 proceeds to step 1060 where direct control signal postprocessing is executed. If the query is negatively answered, method 1000 proceeds to step 1055.

In step 1055, method 1000 queries whether a start code has been received and whether initialization is presently in progress. Namely, it is possible that although host dependent section 114 is not in condition to receive control signals from the host computer at step 1050, but it may be in active condition pending the completion of initialization that is currently in progress. If the query is affirmatively answered, then step 1055 proceeds to step 1060. In other words, method 1000 checks if the previously read data from the digital input ports represents a predetermined initialization and reset code. If so, direct digital control is activated, and method 1000 proceeds to step 1060 where the digital control signal postprocessing is executed.

If the query is negatively answered, then step 1055 proceeds to step 1050 and waits for the activation of the host dependent section 114. Namely, if the appropriate initialization and reset code is not present, digital control remains inactive, and returns to step 1050.

It should be noted that step 1060 and can be called to service new data on the digital input ports by two primary means: polling the input ports for new data, or responding to hardware interrupts generated by the microcontroller 320 as determined by the capability of the selected microcontroller. This polling and/or interrupt response occurs to insure that no vital digital control signal data is missed.

In step 1070, method 1000 receives either postprocessed audio signals from step 1065 or postprocessed direct digital signals from step 1060. Using these postprocessed signals, method 1000 generates the necessary and appropriate

sounds to be preamplified, such that the velocity or engine activity cue can be translated into useful tactile feedback, while not affecting louder sounds in the same manner. These two steps operate by comparing the current calculated audio result, either bass signal, midrange signal, or treble signal to its appropriate PREAMP QUALIFIER. If any given calculated audio result is higher than its appropriate PREAMP QUALIFIER, the calculated audio result is disqualified for preamplification, and its PREAMP MULTIPLIER is not implemented. However, if any given calculated audio result is lower than its appropriate PREAMP QUALIFIER, the calculated audio result is qualified for preamplification, and therefore multiplied (e.g., amplified) by its PREAMP MULTIPLIER. The result of this calculation cannot be larger than the PREAMP QUALIFIER value that qualified the multiplication in the first place. If the result of this calculation is larger than the PREAMP QUALIFIER value, the result is set equal to the PREAMP QUALIFIER value. This eliminates the possibility that quiet sounds will become over amplified.

In step 1240, the next parameter is the EQUALIZER. This step allows a current calculated audio result to be reduced or amplified, e.g., equalized, by some factor. Specifically, the equalizer provides for effectively multiplying any given calculated audio result by any number between 0.00 and 8.00, with 0.03 increments. This yields approx. 32 levels of reduction from 0% to 97% of the original value in approximately 3% steps (e.g., multiplying any given calculated audio result by any number between 0.00 and 0.97). This also yields approx. 265 levels of amplification from 103% to approximately 800% of the original value in approximately 3% steps (e.g., multiplying any given calculated audio result by any number between 1.03 and 8.00 in 0.03 steps). Although this equalizer range is very effective, the present invention is not limited by any default values or how this function is mathematically or otherwise implemented, and/or to the resolution and limits of such calculations.

In step 1250, the next parameter is MAXIMUM. This parameter limits the result of the EQUALIZER multiplication result to some highest allowed value, or maximum, e.g., no higher than 75% of the maximum level. The MAXIMUM parameter limits high equalization results when relatively high amplitude signals are generated by the host computer 102. The MAXIMUM parameter is useful when high equalization values are used, and affected upon high amplitude audio signals.

In step 1260, the next parameter is the RISE RATE. This parameter establishes a maximum allowable rise rate between two sequential audio samples. If the difference between a current digital audio sample and its corresponding prior sample is a positive value that exceeds the RISE RATE parameter, e.g., a value corresponding from 20 ms. to 2 seconds, then the RISE RATE parameter is added to the prior of the two sequential samples, and the result is used in place of the most recent calculated audio result, thereby effectively yielding a reduced rise rate, in accordance with the RISE RATE parameter.

In step 1270, the next parameter is the DECAY RATE. This parameter establishes a maximum allowable decay rate between two sequential audio samples. If the difference between a prior digital audio sample and its corresponding current sample is a positive value that exceeds the DECAY RATE parameter, then the DECAY RATE parameter is subtracted from the prior of the two sequential samples, and this result is used in place of the most recent calculated audio result, thereby effectively yielding a reduced decay rate, in accordance with the DECAY RATE parameter.

In steps 1280-1294, the last four parameters function together to provide a means of interpreting various audio amplitude inducing simulated events, and subsequently generating an appropriately strong tactile response. Essentially, it is very important to recognize abrupt increases in audio amplitude over some number of sequential digital audio samples. In games or simulations, any number of generally traumatic events can occur that will require a very powerful response by the tactile feedback controller 110 when it is operating in its host-independent audio analysis mode. For example, a simulated car being driven by the simulation user may bump another simulated car, or crash into a simulated object at a high velocity. Likewise, a simulated enemy missile or other simulated offensive/defensive weapon may strike a simulated vehicle being piloted by the simulation user. These types of simulated events, and others like them, are typically accompanied by an abrupt and varied rise in the amplitude of some appropriately provided sound effect (hereafter referred to as a "crash" event). However, this rise in audio amplitude may not inherently have enough power, and/or may not last long enough, to cause a powerfully appropriate tactile feedback event to match the simulated event.

In order to rectify this shortcoming, in steps 1280 and 1290 the next two parameters, CRASH MAGNITUDE and CRASH TIME SPAN, together allow the combined magnitude and time span of an abrupt rise in the digitally sampled audio to generate a "crash" response. The tactile feedback resulting from this "crash" response is then controlled by the last two parameters in step 1292 and 1294, CRASH HOLD and CRASH FADEOUT. The CRASH MAGNITUDE parameter establishes the minimum rise in sampled audio amplitude that will qualify as a "crash" event. The CRASH TIME SPAN parameter establishes the maximum time allowed for an acceptable CRASH MAGNITUDE rise to develop. For example, these parameters may look

designated as PORT A, PORT B, or their respective equivalents. Thus, the preferred embodiment is only an illustrative approach, as communication bus of different sizes and types can be employed.

The device values physically implemented by any single tactile feedback controller 110 are generally limited to the number of I/O pins that are provided for Pulse Width Modulation (PWM) control signal output. Therefore, it is likely that the range of possible device values transmitted over PORT A may outnumber any given single implementation of PWM control signal generation output pins. In the present preferred embodiment, the microcontroller 320 has 8 I/O pins designated as control signal output pins.

Although the current 4-bit PORT A is permitted to transmit up to 16 different device pointer values, the microcontroller 320 can only provide 8 I/O pins. As a result, it is entirely possible for a transmitted PORT A device value to designate a specific device that is not physically implemented by any given tactile feedback controller 110 that may receive that device value. In such cases, that specific control signal is ignored by each tactile feedback controller 110 for which that signal is invalid.

The present invention is designed in such a way that many tactile feedback controller 110 can be daisy chained together, by providing a pass-through parallel port 117 on each controller. In this manner, each and every tactile feedback controller 110 connected to the same communication bus will receive the same control signal, including the same device pointer value. However, each tactile feedback controller 110 may control a completely different and independent set of tactile sensation generators, by only responding to some subset of the possible device pointer values that it may receive. Tactile sensation generator hardware that is connected to one tactile feedback controller 110 may not be present on another controller. Each microcontroller 320 has some limited number of available I/O pins that individually control the transistor switch circuits 350 that subsequently power some configuration of multiple independent tactile sensation generators 120. Therefore, different tactile feedback controllers 110 can be designed to respond to some subset of the possible device pointer codes that it may receive. If a device pointer value is received that is not implemented by a specific tactile feedback controller 110, then that device pointer and its accompanying activity value will be ignored by that specific controller.

Returning to FIG. 13, method 1060 starts in step 1305 and proceeds to step 1310 where method 1060 queries whether the received PORT A device value is valid in view of the current specific hardware implementation. If the query is negatively answered, i.e., if the PORT A device value is not valid for the specific hardware implementation, then method proceeds to step 1320 where the entire digital control signal is ignored. If the query is affirmatively answered, i.e., if the PORT A device value is valid for the current specific hardware implementation, method 1060 proceeds to step 1330, where the PORT A device value is accepted as a valid device pointer.

In step 1340, the PORT B value is then accepted as the device activity value (for the device that is pointed to by PORT A). Method 1060 then ends in step 1345 or returns to step 1070 of FIG. 10, where control signals for the tactile sensation generators 120 are generated.

FIG. 14 is a flow chart of a method 1070 for generating control signals for tactile sensation generators. Namely, it is a flow chart that illustrates the processing step of 1070 in FIG. 10. Method 1070 starts in step 1405 and proceeds to step 1410, where device values and device activity values are written to a digital control signal table (1510 shown in FIG. 15) in the RAM 342 of the microcontroller 320. Namely, under the host dependent mode, the PORT A device value designates a specific numbered entry in an internal RAM based digital control signal table (illustrated in FIG. 15) that ultimately stores the PORT B device activity value. In this manner, an internal digital control signal table is maintained within the microcontroller 320 that holds all of the digital control signal data that is generated by the host computer 102.

The internal RAM based digital control signal table was initialized with zeros upon the last power on reset. Therefore, the default "device activity" value of each entry in the digital control signal table is a zero. The only event that can change the value of an entry in the digital control signal table is a valid digital control signal. The PORT A device value actually points to the numbered entry in the table that is to be changed. The PORT B activity value is the actual value that is inserted into the appropriate device entry in the digital control signal table. In other words, the PORT B value is put into the digital control signal table at the device entry pointed to by PORT A. These table updates occur in real time when the host computer 102 changes its digital output signal, by hardware interrupts triggered by interrupt driven input ports on the microcontroller 320, or by polling the input ports at frequent intervals as determined by the ROM code within the microcontroller 320.

various types of actuators can exists in many different sizes, with many different power requirements and operating ranges of power consumption for each implementation. In order to accommodate the wide range of electromechanical devices that can be controlled by the universal tactile feedback controller 110, each specific device type can impose limits on the power signals that it will accept. This is accomplished by reprogrammable device specific power output parameters 1520. Although the presently preferred embodiment uses three device specific power output parameters 1520 for each device, no specific limitation is to be inferred with regard to additional device specific power output parameters that may be useful for any given specific type of device or actuator that may be implemented by the system of the present invention.

The first device specific power output parameter 1520 is determined by the main power supply voltage in use by the universal tactile feedback controller 110, and the power supply range that is appropriate for any given tactile sensation actuator 501. In order to tailor the power supply voltage so that it becomes appropriate for any given device, a "duty cycle" power output parameter is used. For example, if the main power supply applied to a given device specific transistor switch circuit 2551-2558 (see FIG. 25) is 20 volts, and a specific tactile sensation actuator 501 that is to be driven by that transistor switch circuit 2551-2558 has been rated for a 12 volt power supply, a device specific power output "duty cycle" parameter can scale the provided device activity value to 60% of its original value before inserting it within the appropriate device entry in the PWM control signal table 1530. This will effectively create an average maximum power level of 12 volts, which is the rated power range for the tactile sensation actuator in question. By multiplying any given device activity value by a device specific "duty cycle" power output parameter 1520 (e.g., a number between 0.00 and 1.00 in 0.03 increments), the universal tactile feedback controller 110 can use one power supply to support many different devices. Furthermore, the "duty cycle" can be set above 100%, to increase the power to any given tactile sensation actuator when that device is operating at less than the actual provided voltage (e.g., you can not convert a 20 volt signal into a 40 volt signal by setting its duty cycle at 200%). Allowing device specific duty cycle parameters can reduce the complexity and cost of the universal tactile feedback system 100 by allowing a single main power supply to support the individual power requirements of many different devices. However, the presently preferred embodiment makes no exclusion to using individual power supplies or regulated voltage lines for each device that may be implemented by the present invention. In fact, the presently preferred embodiment uses two voltage sources in order to limit reliance on "duty cycle" parameter implementation. If a main power supply voltage of 20 volts was being used to drive a tactile sensation actuator 501 with a maximum operating voltage of 5 volts, that device would have to use a 25% duty cycle parameter. Although this setting can be used, it would effectively reduce the maximum possible pulse width "ON" time to no more than ¼ of its normal "ON" time at a 100% duty cycle. This may create "choppy" actuation within the actuator, as it would be receiving 20 volts for 25% of the time, and 0 volts for 75% of the time, for a PWM average of 5 volts. A better implementation would be a supply voltage of 10 volts at 50% duty cycle, which is why the presently preferred embodiment incorporates just such a second voltage line.

The second device specific power output parameter 1520 is determined by the user's personal intensity preferences with regard to the desired intensity that is to be generated by any given tactile sensation actuator 501. Due to the different types and numbers of tactile sensation actuators that can be simultaneously driven by the universal tactile feedback controller 110, the user may desire to individually reduce or increase the tactile feedback generated by any given actuator. Although the "duty cycle" parameter sets the operating range of voltage that can be applied to any given actuator, the duty cycle setting is determined solely by the power requirements of a specific actuator. The "personal intensity preference" device specific parameter is determined solely by the user's personal preference with regard to the tactile feedback produced by any given specific tactile sensation actuator 501. This parameter is implemented in a similar way to the duty cycle parameter, in that the device activity value is multiplied by the appropriate device specific intensity parameter (e.g., a number between 0.00 and 2.00 in 0.03 increments).

The third device specific power output parameter 1520 is a "minimum activation value" which determines the activity threshold below which any given device will remain off. In the presently preferred embodiment, the minimum activation value parameter is not applied to non-zero device activity values, as non-zero device activity values necessarily mean that a given device is currently under direct digital control. If a device has a zero device activity value in the digital control signal table 1510, then that device is being ignored by the host computer for as long as the zero activity value is present (e.g., that device is in the "follow the master" mode). For example, imagine a device that has a minimum activation value of 70%. As long as the master device (device 0) activity value is less than 70% of the possible maximum value, the PWM value for that device in the PWM control signal table 403 will always be zero, and that device will remain OFF. If and

device code 9). Sending the single command pair "device 9, activity 1" (equivalent to PORT A 9, PORT B 1) will turn all such devices off, by loading each directly controlled device's digital control signal table 1510 activity entry with same activity value (PORT B=1) that was sent to device 9 (PORT A=9). The processing that accomplishes this occurs entirely within the microcontroller 320, and does not require any additional digital control signal data from the host computer 102.

FIG. 16 is a flow chart of the batch data transmission method used in step 1035 of FIG 10. Batch data transmissions are used to reprogram various operational parameters within the tactile feedback controller 110. The batch data transmission method is invoked by the method 1000 of FIG. 10 when a batch data transmission trigger is present on the digital input ports PORT A and PORT B. In the preferred embodiment, the batch data transmission trigger is composed of two alternating strobe signals that repeat four or more times. The first strobe signal is PORT A = 15, PORT B = 7, and the second strobe signal is PORT A = 15, PORT B = 8. Essentially, PORT A is set to the value 15, and PORT B alternates/strobes between the values 7 and 8, at an approximate minimum interval of 3 milliseconds. These strobe signals can be repeated as many times as necessary to ensure that they are received by the microcontroller 320. This batch data transmission trigger could be implemented in many other ways, however, while still achieving the same end, e.g., activating the batch data transmission method's receive mode.

Returning to FIG. 16, method 1600 starts in step 1605, and proceeds to step 1610, where method 1600 checks if all the required trigger strobes have been completed. If they have not been completed, step 1615 checks to see if the next trigger strobe timer has expired. This trigger strobe timer exists as a safety to make sure that each valid trigger strobe follows the prior strobe by no more than some maximum time frame, such as 0.200 seconds. If a trigger strobe stagnates or deviates from the expected sequence before it completes the necessary strobe count, the trigger strobe counter is reset in step 1620, and subsequently returns to step 1630. This insures that the batch data transmission receive routine is not invoked unless a valid trigger set is received in a timely fashion. If the trigger strobe timer has not expired, the batch data transmission method continues to wait (e.g., does not reset the counter) for the next trigger strobe component in step 1625, and subsequently returns to the main software loop in step 1630.

Alternatively, if the batch data transmission method 1600 determines in step 1610 that all of the required trigger strobes have been received (typically 4 pairs of strobe triggers), the actual batch data transmission receive mode is entered in step 1635.

In the preferred embodiment, the batch data transmission method is a one way communication. To ensure the validity of the data received, a robust lock step method is used. Although the preferred embodiment has implemented this illustrative approach, any data transmission method could equally be used in its place, provided the appropriate corresponding method was implemented in the software that generates the actual data transmissions, and the ROM code within the microcontroller 320 that receives those same data transmissions. The preferred embodiment makes no specific exclusion to using some other data transmission routine and/or the trigger that signifies the start of the communication.

Returning to FIG. 16, each cycle through the batch data transmission receive mode begins at step 1665, by waiting until a zero appears on PORT A. Steps 1665 and 1670 together yield an endless loop that is only broken when the external software sets PORT A equal to zero. After PORT A equals zero, the external software sets PORT B equal to the value it wishes to transfer in step 1675. In the meantime, steps 1680 and 1685 together yield an endless loop that is only broken when PORT A does not equal zero. In this way, the external software can allow PORT B to stabilize before the external software transmits a non-zero PORT A value. The next non-zero value on PORT A may be the "end transmission" code, which the preferred embodiment sets as 15. If this "end transmission" code is present, step 1690 recognizes it, exits the data transmission receive mode in step 1660, and ultimately returns to the main software loop via step 1630. If the end transmission code is not present, the non-zero value that appears on PORT A will be a pointer for a permanently encoded table in the ROM of the microcontroller 320. This pointer determines which reprogrammable internal parameter within the RAM of the microcontroller 320 will be changed to the PORT B value. This is illustrated in step 1655. In order to insure that the PORT B value is legal for the parameter that is pointed to by PORT A, each parameter has internal checks to make sure the PORT B value will not cause undesirable operation if and when it is implemented. If the PORT B value is illegal for the parameter pointed to by PORT A, the value is rejected in step 1640, and the entire cycle begins again in step 1665. If the PORT B value is legal for the parameter pointed to by PORT A, the value is accepted into the designated parameter in step 1645, and the entire cycle begins again in step 1665. In cases where the amount of reprogrammable parameters outnumbers the range of values capable of being transmitted on PORT B (in this case, 4 bit PORT B can transmit values 0-15, with 0 and 15 used to begin and

FIG. 18 is a flow chart of a "user intervention" method 1800 to trigger the batch data transmission method. Method 1800 starts in step 1805 and proceeds to step 1810 where method 1800 loads the default settings from the default configuration file. Then, step 1820 presents a graphical user interface so the user can easily manipulate all of the configuration data. Included in this "manipulation of configuration data" is loading both specific and default configuration files. In order to load any given configuration file, the user will typically select the file from a directory listing, which can be browsed with a mouse or other pointing device. Loading a given configuration file, or changing any single configuration parameter, are both interpreted as changes in the configuration data in step 1830. While both versions 1700 and 1800 of the batch data transmission software application can transmit the complete configuration data set, the graphical user interface user intervention method 1800 can transmit individual parameters as they are manipulated by the user in step 1860. By transmitting changes in configuration data to the tactile feedback controller 110 as they occur in step 1860, the user can efficiently discover optimal specific configuration data settings while the tactile feedback system 100 is in use. This is especially useful for discovering the best audio analysis parameters. When the configuration data is acceptable, the user can save the current configuration data in step 1840. The method then saves the appropriate type of configuration file (default or application specific), creating new files when necessary in step 1870. The user can terminate the user intervention version 1800 by using an exit option in step 1850 to arrive at step 1875.

When application specific configuration files are created for use with the host-independent audio analysis mode of operation, audio analysis calibration instructions are provided within the application specific configuration files. In order for the audio analysis mode to be most effective, the audio signal produced by the host computer 102 must be consistent with the audio signal that was used to set the audio analysis parameters that are contained within a given specific configuration file. This consistency between the audio signal from the host computer 102 and the audio signal that was used to set the audio analysis parameters is achieved with the host-independent audio analysis calibration routine 1900 of FIG. 19.

Referring to FIG. 19, the calibration method 1900 begins with step 1905 and proceeds to step 1910, wherein the user loads the desired application specific configuration file with either batch data transmission software 1700,1800. In the case of the no user intervention version 1700, the provided audio analysis calibration instructions are displayed for the user on screen 1740 (see FIG. 17). In the case of the user intervention version 1800, the provided audio analysis calibration instructions must be selected for display by selecting them from a graphical pull-down menu. In either case, the user takes note of the provided calibration instructions in step 1920. This can include printing the provided instructions. After the user has taken note of the calibration instructions, the user runs the desired application in step 1930.

The calibration instructions were created, at some point in time, typically with the user intervention method 1800 of the batch data transmission software application. Within that method 1800, a text editor is provided so calibration instructions can be recorded. When an application specific audio analysis calibration file is being created, and the audio analysis settings are acceptable to the person creating the file, the calibration potentiometer (component part R8 of FIG. 6) within the variable gain pre-amplifier 420 of the analog audio signal pre-processing section would have been previously adjusted to the satisfaction of the person creating the configuration file. The calibration potentiometer adjusts the signal strength of the audio signal such that the audio signal is neither too weak, nor too strong. When the audio analysis parameters are yielding good results, the person creating the calibration instructions looks to find a relatively common sound effect occurring within the simulation. When the person who is creating the calibration instructions hears a common sound effect, they observe the status of the LEDs within the system analysis display. Within the calibration instructions, they describe what common sound effect to listen for, and the number of LEDs on the system analysis display that are illuminated in response to the common sound effect (when the calibration potentiometer is properly set).

Referring again to FIG. 19, the user waits until the desired application is generating the common sound effect that was specified in the calibration instructions. When the specified sound effect is heard in step 1940, the user adjusts the calibration potentiometer (via knob 2430 of FIG. 24) until the LEDs within the system analysis display appear approximately as specified within the calibration instructions. When the LEDs within the system analysis display 370 appear approximately as specified in the calibration instructions, indicated by step 1950, it means the audio signal generated by the host computer 102 is occurring at the same approximate amplitude as the audio signal that was used to set the application specific audio analysis parameters. Once the audio signal from the host computer 102 is an approximate match to the original audio signal that was used to set the audio analysis parameters, the tactile feedback resulting from the audio analysis mode of operation will be substantially similar to the results perceived by the person who created the corresponding specific configuration file. In other

2450, and the LED display 370) allows important values to be manipulated directly from the tactile feedback controller 110 itself, without external software running. Although the preferred embodiment has implemented these three switches, the present invention makes no limitation on how these switches can be implemented, if at all. Furthermore, additional switches may prove useful, and no specific implementation is declared to limit some other set of switches, or lack thereof. This set of hardware switch multiplexer method 2100 repeats steps 2110-2130.

FIG. 25 is a functional block diagram of both the multiple independent PWM control signal generation component 2504, and the PWM outputs 2540 of microcontroller 320. Each of the eight individual PWM independent control signal output pins 2541-2548 renders a PWM signal as dictated by its corresponding value in the multiple independent PWM control signal table. Each of these independent PWM output signals 2541-2548 controls a corresponding independent transistor switch circuit 2551-2558. The eight transistor switch circuits 2551-2558 together comprise the transistor switch circuits 360 component of FIG. 3. Each microcontroller PWM output pin 2541-2548 is used by one transistor switch circuit 2551-2558 to turn on and off one or more tactile sensation actuators 501 within some independent tactile sensation generator (depicted as 502, 503, 504). A given transistor switch circuit 2551-2558, in response to the output of its corresponding PWM output pin 2541-2548, becomes activated, e.g., conducts current, such that the appropriate transistor switch circuit 2551-2558, once activated, allows current to pass through one or more actuators 501 to ground. In response, the actuators 501, e.g., DC motors with offset weights attached to their shafts, vibrate. As a PWM signal 2541-2548 that drives a DC motor increases its pulse width, the DC motor receives more current and spins faster, thereby yielding more powerful tactile sensation (e.g., vibration). Although the PWM output signals 2541-2548 provide a wide range of pulse widths, some actuators 501 (such as solenoids) may require only a digital type signal composed of two pulse widths: ON (e.g., 100% pulse width), and OFF (0% pulse width), which correspond to binary 1 and binary 0, respectively. In such a case, the PWM output signals can be limited accordingly, when necessary. Furthermore, the microcontroller 320 does not necessarily have to use the Pulse Width Modulation technique to control the transistors 2550 and actuators 501 it controls. Many other techniques can readily be implemented by those skilled in the art.

In the presently preferred embodiment, each single tactile feedback controller 110 provides eight independent outputs 2541-2548 that are driven in the previously described manner. However, there is no specific limitation imposed on how many such outputs are to be provided within any single tactile feedback controller 110. The only limiting factor is the number of I/O pins available on the microcontroller 320. Furthermore, many microcontrollers 320 can be working in parallel to provide as many I/O pins as are necessary to sustain any imagined implementation. Additionally, many tactile feedback controller 110 units can be daisy chained together, theoretically allowing as many tactile feedback controller 110 units to provide as many desired outputs as the electrical properties of the connections in the host computer 102 allow, until the total resistance and capacitance of the cables in such a configuration prohibitively degrade the transmission of that information. Even in such a case, analog and digital signal hubs can be used to boost the signals carried over the connections.

Ultimately, the PWM signals 2541-2548 that control the outputs from the transistor switch circuits 2551-2558 can be used to control any electromechanical device. Each transistor switch circuit 2551-2558 can use its own power supply and transistor type that is appropriate for the actuator or actuators that it is intended to drive. There should be no inferred limitation regarding the power consumption of any given actuator based upon the PWM signal 2541-2548 that controls it. However, for simplicity, this disclosure generally implies DC motors with offset weights for its tactile sensation actuators 501. As a PWM signal 2541-2548 that drives a DC motor increases its pulse width, the DC motor receives more current and spins faster, thereby yielding more powerful tactile sensation (e.g., vibration).

The illustrated independent tactile sensation generators 502, 503, 504 can contain one or more independent tactile sensation actuators 501, with each independent tactile sensation actuator 501 containing one or more individual actuators working in series or parallel. For example, independent tactile sensation generator 502 contains one set of tactile sensation actuators 501 which responds to one transistor switch circuit 2551. Independent tactile sensation generator 503 contains three sets of tactile sensation actuators 501 which independently respond to three transistor switch circuits 2552, 2553, 2554. Independent tactile sensation generator 504 contains four sets of tactile sensation actuators 501 which independently respond to four transistor switch circuits 2555,2556,2557,2558. Each tactile sensation actuator 501 can be composed of many individual actuators that are wired in series or parallel, that function as a single tactile sensation actuator by responding to the same PWM signal. Ultimately, tactile sensation actuators 501 can be arranged in any number and configuration, with one or more tactile sensation actuators 501 existing within one or more independent tactile sensation generators 502, 503, 504. 460

where this device is ignored by the host computer 102, the appropriate "minimum activation value" power output parameter can be set such that this device only produces tactile sensation upon a crash event, for example. In this way, the illusion of restraint by a seat belt or safety harness can be produced.

In FIGs. 27-28, both the tactile sensation actuator(s) for the left pedal on a rudder control 550, and the tactile sensation actuator(s) for the right pedal on a rudder control 560, together comprise a pair of independent tactile sensation generators that can be affixed to or embedded within both pedals on a rudder pedal unit. Generally, these actuators may be attached to pre-existing rudder pedal units, or may be embedded within the plastic or metal structure that comprises the rudder pedals during their manufacture. In one implementation, vibratory actuators are embedded within corresponding plastic pedal overlays, such that when the plastic overlays are laid on top of the existing foot pedals, and affixed in place with hook and loop fasteners or two sided adhesive foam tape (or some other readily available attachment means), the new surfaces of the foot pedals contain the tactile sensation actuators. In another implementation, tactile sensation actuators are affixed to the bottom of the existing foot pedals, with hook and loop fasteners or two sided adhesive foam tape, if there is sufficient space for the actuators beneath the pedals. These approaches are illustrated later in this disclosure. In addition to allowing specific tactile sensations to be perceived via the rudder pedal control input device, the rudder pedal unit will be afforded the illusion that it is affixed to the same structure to which the seating unit is affixed. This begins to provide the illusion that there is a continuity of structure among the disparate control input devices that is important for suspending the disbelief of the simulation user.

In FIG. 26A, the tactile sensation actuator(s) for a stand alone throttle and weapons controller 530 will generally be comprised of two possible forms. In the preferred illustrative form, a vibratory actuator can be attached to outer side of the throttle handle with hook and loop fasteners or two sided adhesive foam tape (or some other readily available attachment means), such that the actuator is substantially out of the way, and therefore will not interfere with the motion of the throttle body or the ergonomics of the throttle handle. In a second illustrative form, small vibratory actuators can be affixed to or embedded within the throttle's handle, such that the hand of the user, in holding the throttle, will come into direct or indirect contact with these small vibratory motors. If these motors are attached to the outer surface of the throttle handle, they must be small enough to not substantially disrupt the ergonomics of the throttle handle. A preferable location would be the underside (bottom) of the throttle handle. They may be attached in a temporary fashion via small elastic straps, or they may be embedded within a small plastic housing that is specifically designed to fit precisely upon the surface of a specific location of a specific throttle handle. Alternatively, small motors may be inserted into the palm area of a padded glove that is to be worn by the user. In another illustrative form, larger actuators can be affixed to the base of the throttle unit, by Velcro or two sided adhesive foam tape, which will generally alleviate possible size and ergonomic restraints. Larger actuators can be more powerful, and therefore, will vibrate the handle of the throttle by sympathetic vibration. Additionally, both of these implementations of actuators may be used simultaneously.

The tactile sensation actuator(s) for a flight control joystick 540 are implemented in a similar fashion to the actuators for the throttle and weapons controller 530. In the preferred illustrative form, vibratory actuators can be affixed to or embedded within the joystick's handle, such that the hand of the user, in holding the joystick, will come into direct or indirect contact with these vibratory motors. If these motors are attached to the outer surface of the joystick handle, they must be small enough to not substantially disrupt the ergonomics of the joystick handle. A readily available solution are small 5 mm micro-motors, typically used as vibrators for pocket size pagers. These micro-motors can be mounted to the palm side of the joystick handle. The actuators may be attached in a temporary fashion via small elastic straps, or they may be embedded within a small plastic template/housing that is specifically designed to fit upon the relatively flat surface of the palm area of a joystick handle. Many force-feedback joysticks have optical sensors on the joystick handle to determine when the joystick is being held. In these cases, the template must accommodate the optical sensor, by being made of transparent plastic, or by providing an appropriate hole, such that light can strike the optical sensor when the joystick handle is not being held. Alternatively, small motors may be inserted into the palm area of a padded glove that is to be worn by the user. In a second illustrative form, a vibratory actuator can be attached to lower side of the joystick handle opposite the user's palm, with Velcro hook and loop fasteners or two sided adhesive foam strips, such that the actuator is substantially out of the way, and therefore will not interfere with the motion of the joystick or the ergonomics of the joystick handle. If sufficient room does not exist in this location, the very top of the joystick usually has sufficient area to attach an actuator. However, this area is more conspicuous, and therefore, the size and shape of the actuator housing may be especially limited by aesthetic considerations.

the driving simulation user will benefit from the illusion that these disparate devices are all attached to the same physical structure.

In FIG. 26D, the first person perspective open-body combat game, the central tactile feedback device is a vest-based tactile sensation generator 595. This vest-based tactile sensation generator can apply localized tactile sensation, typically via vibratory and solenoid based actuators, to many areas around the game player's torso. In this manner, environmental stimuli (e.g., bullet strikes, weapon strikes, energy fields, and so on) can be rendered in a directional manner. This can provide the game user with information regarding the location of the source, and the strength and direction of the attacks or stimuli. FIG. 39 illustrates a front and side view of a vest-based tactile sensation generator, respectively. U.S. Patent 5,565,840 "Tactile Sensation Generator" is such a device. The vest-based tactile sensation generator 595 has additional uses as well. In vehicle simulation scenarios, such as those illustrated in FIGs. 27-29, the vest based tactile sensation generator 595 can render directional G forces during vehicle maneuvering. FIG. 26D also includes a tactile feedback seating unit 510 as previously described. As games and simulations get more complex, it is becoming more common to have games where the mode of transportation changes from a simulated character who is walking, running, or otherwise navigating through the simulated environment, who then jumps into some available vehicle, and then proceeds to drive the vehicle. In this case, the tactile feedback seating unit 510 can generate appropriate tactile feedback as necessary. Therefore, in many cases, the vest-based tactile sensation generator 595 and the tactile feedback seating unit 510 can work interchangeably, or simultaneously, in a synergistic fashion.

The number of control input devices that can be used to control any given first person perspective shooter are as numerous as the types of controllers that exist in the marketplace. Joysticks, 360 degree spin controllers, gamepads, mice, trackballs, light guns, and 3D controllers, are some of the types of controllers that are available. In FIG. 26D, for simplicity, the peripheral tactile sensation actuators are described by the human appendage they are intended for. The tactile sensation actuator for the left hand 590 and right hand 591 can exist within the appropriate device or devices, within a pair of gloves worn by the user, or can be attached to the appropriate device or devices with elastic straps. The tactile sensation actuators for the left foot 592 and right foot 593 can be worn by the user via elastic straps, or, where applicable, can be attached to or embedded within the appropriate control input device or devices.

Generally, all of the peripheral tactile sensation actuators of FIGs. 27-30 are vibratory motors enclosed in plastic housings that have some simple attachment means for attaching the vibratory motors to a given control input device. The vibration produced by any given motor can effectively transmit through its hard plastic housing and the attachment means, ultimately causing vibration within the attached control input device. The size and shape of the motor and its plastic housing are determined by the control input device they are meant to be attached to. The attachment means is most often hook and loop fasteners, although many other attachment means are readily available. In most cases, a peripheral tactile sensation actuator will be comprised of a DC motor with an offset weight on its shaft, a capacitor and diode across the motor's terminals, with a four to eight foot power distribution cable, that ends in some appropriate power connector. The electronic apparatus within each actuator is very simple, and the housing and attachment means can be readily adapted to accommodate any given device. All four scenarios depicted in FIGs. 27-30, and the tactile sensation apparatus within those scenarios, are illustrative. The provided scenarios should not be interpreted to imply any specific limitations on possible tactile sensation actuators, tactile sensation generators, and the control input devices that they are applied to or embedded within.

In FIGs. 27-30, the tactile feedback seating unit 510 is a semi-rigid flexible foam structure, sealed with a cloth or vinyl layer, with a leg portion and a back portion, substantially shaped to easily rest upon any given seat, with a plurality of actuators embedded within the foam structure, such that the actuators in the pad produce localized vibration. These actuators are laid out in several independent zones within the foam, providing a left leg tactile sensation generator, a right leg tactile sensation generator, and a back tactile sensation generator (which may itself be divided into left back and right back tactile sensation generators), such that these independent tactile sensation generators exist within the single tactile feedback seating unit 510. Furthermore, each tactile sensation generator zone within the seat may itself be made up of one or more tactile sensation actuators 501. Illustrative examples regarding tactile feedback seating units are depicted in FIGs. 31-33.

In FIG. 27A, the tactile feedback seating unit 510 is composed of a semi-rigid flexible foam structure 512, within which six actuators 501 are embedded. The embedded actuators are arranged into three pairs, providing a back tactile sensation generator zone containing two actuators connected to power distribution line 461, a left leg tactile sensation

together to solidly seal the motor within the housing 800. In FIG. 29E, a solenoid 820 uses its plunger 822 to strike the housing 800 when the solenoid is energized by its power distribution cable 460. A return spring 824, and a spring restraint pin 826 (or equivalent) force the plunger 822 to return to its initial position when the solenoid is de-energized. In other implementations, the solenoid plunger can actuate a lever that pushes through an opening in the housing 800, such that the lever can strike an object outside of the plastic housing 800. Generally, any number of applications can be derived from the productivity of motors 810 and/or solenoids 820. The activity of any given motor or solenoid can effectively transmit through its hard plastic housing and an attachment means, ultimately causing sympathetic vibration or other tactile event within the attached control input device. The size and shape of the motor 810 and/or solenoid 820, and the plastic housing 800, are determined by the control input device they are meant to be attached to, and the desired effect. In any case, the housing 800 is attached to the desired control input device by some attachment means.

In FIG. 30A, the housing 800 has an attachment means of a two-sided adhesive strip 830. In FIG. 30B, the housing 800 has an attachment means of two corresponding halves of hook and loop fasteners. Typically, the hook half 840 of the attachment means is attached to the housing 800, and the loop half 842 of the attachment means is attached to the desired control input device. This yields a less permanent attachment means than two sided adhesive strips. In FIG. 30C, the loop fastener 842 is not attached to the desired control input device, but is instead attached to one end of a strap 841 of elastic fabric, non-elastic fabric, rubber, or some other material. The other end of the strap 841 is permanently attached to the housing 800. This allows the strap 841 to hold the housing 800 tightly against the desired control input device. This solution is the least permanent attachment means.

The attachment means is most often the hook and loop fasteners of FIG. 30B, although many other attachment means are readily available and can be substituted as necessary. Generally, a peripheral tactile sensation generator will be comprised of a DC motor with an offset weight on its shaft, all within a plastic housing, with an eight to ten foot power distribution cable 460, that ends in some appropriate power connector for the power jacks illustrated in FIG. 26. Essentially, the electronic apparatus within each peripheral tactile sensation generator is very simple, and the housing and attachment means can be readily adapted to accommodate any given device. All four scenarios depicted in FIGs. 27-30, and the tactile sensation apparatus within those scenarios, are illustrative. The provided scenarios should not be interpreted to imply any specific limitations on possible tactile sensation actuators, tactile sensation generators, and the control input devices that they are applied to or embedded within.

In FIG. 26A, the tactile sensation actuator(s) for a stand alone throttle and weapons controller 530 will generally be comprised of two possible forms. In the preferred form, small vibratory actuators can be affixed to or embedded within the throttle's handle, such that the hand of the user, in holding the throttle, will come into direct or indirect contact with these small vibratory motors. In one illustrative form, a vibratory actuator can be attached to outer side of the throttle handle with hook and loop fasteners or two sided adhesive foam tape (or some other readily available attachment means), such that the actuator is substantially out of the way, and therefore will not interfere with the motion of the throttle body or the ergonomics of the throttle handle. This is illustrated in FIGs. 45-52.

FIG. 31A is a rear side view of a center-mounted throttle. FIG. 31B is a top down view of a center- mounted throttle. FIG. 31C depicts a throttle tactile sensation generator 530 attached to the outer side of the throttle handle with the attachment means of FIG. 30B, such that when the throttle is moved through its range of motion, the tactile sensation generator 530 does not interfere with the motion of the throttle or the ergonomics of the throttle handle. FIG. 31D is a top down view of the apparatus of FIG. 31C, showing the position of the throttle tactile sensation generator 530. FIG. 31E is a rear side view of a side-mounted throttle. FIG. 31F is a top down view of a side-mounted throttle. FIG. 31G depicts a throttle tactile sensation generator 530 attached to the outer side of the throttle handle with the attachment means of FIG. 30B, such that when the throttle is moved through its range of motion, the tactile sensation generator 530 does not interfere with the motion of the throttle or the ergonomics of the throttle handle. FIG. 31H is a top down view of the apparatus of FIG. 31G, showing the position of the throttle tactile sensation generator 530. In the case of the illustrated throttle tactile sensation generator 530 of FIGs. 47, 48, 51, and 52, power distribution cable 465 is used to power the illustrated tactile sensation generator.

The most preferable solution for the placement of the throttle tactile sensation generators, however, is inside the throttle handle itself at the point of manufacture. This will make the tactile sensation generators invisible. If implemented at the point of manufacture, a small housing for the actuator can be molded directly into the structure of the throttle handle, such that the actuator can be readily affixed to the inside surface of the throttle handle. If implemented as an after market

control input devices that they are applied to. In a preferred implementation, the tactile sensation generators for the steering wheel 570 are attached to one or more of the spokes that connect the steering wheel to its hub, as depicted in FIGs. 69-72.

FIG. 35A is a front view of a steering wheel. FIG. 35B is a side view of a steering wheel. FIG. 35C is a front view of a steering wheel, with tactile sensation generator 570 attached to one spoke on the steering wheel with the attachment means of FIG. 30C. FIG. 35D is a side view of the apparatus of FIG. 35C. In this way, the activity of the tactile sensation generator can propagate through the steering wheel. In another implementation, the tactile sensation generator housing of the steering wheel tactile sensation generator 570 can be implemented as a two part housing, the two parts of which sandwich a given steering wheel spoke, with one of the two parts containing a vibratory motor. The two parts can be fastened together with screws and screw receptacles, or with some commonly implemented equivalent, such as nuts and bolts or mating snap connectors. These connectors could be made to specifically match any given specific steering wheel spoke design, or can be implemented as a general purpose attachment. In other possible implementations, tactile sensation generators could be mounted on the center hub of the steering wheel, or within the steering wheel itself. Additionally, small motors may be inserted into the palm area of a pair of padded driving gloves that are worn by the user.

Referring again to FIG. 26C, tactile sensation generators are mounted to the pedal base unit 580, thereby simulating vibration that would normally be felt through the floor of the vehicle. Essentially, a vibratory actuator within a plastic housing can be attached to the pedal base unit with Velcro hook and loop fasteners or two sided adhesive foam tape. One or more actuators can be used as desired. Tactile sensation actuators can be implemented upon the provided pedals that protrude from the base of the pedal unit, such as gas, brake, and clutch pedals 585. Brake pedal actuator(s) can simulate such things as braking resistance, wheel lock-up, and anti-lock brakes, with vibratory motors or solenoids, or both. Clutch pedal actuator(s) can simulate such things as clutch slippage and poorly timed shifts in a similar manner. These items are illustrated in FIGs. 73-76.

FIG. 36A is a top down view of a pedal unit control input device. FIG. 36B is a right side view of a pedal unit control input device. FIG. 36C is a top down view of a pedal unit control input device, with a pedal base tactile sensation generator 580 attached to the base of the pedal unit, and a brake pedal tactile sensation generator 585 attached to the brake pedal. FIG. 36D is a side view of the apparatus of FIG. 36C. In FIGs. 75 and 76, the attachment means is that of FIG. 30B, while power distribution cable 468 powers the pedal unit tactile sensation generator 580, and power distribution cable 466 powers the brake pedal unit tactile sensation generator 585. In the brake pedal tactile sensation generator 585, a solenoid (see FIG. 29E) and/or a vibratory motor (see FIG. 29C) can be used.

Referring again to FIG. 26C, a tactile sensation actuator is embedded within the shift knob itself 575, when possible. FIG. 37A is a side view of a shift knob upon a shaft. FIG. 37B is a shift knob tactile sensation generator 575, comprised of a housing with two halves 575A and 575B, such that the two halves can accommodate a vibratory motor (see FIG. 29C). A horizontal tightening screw 576 can be tightened such that the shift knob tactile sensation generator 575 becomes firmly attached to the shaft 577. Power distribution cable 465 powers the vibratory motor within the shift knob tactile sensation generator 575. FIG. 37C is equivalent to FIG. 37B in all respects, except that a solenoid (see FIG. 29E) is also contained within the shift knob tactile sensation generator 575. The solenoid is powered by some power distribution cable 460. In FIG. 37D, a dense foam insert 578 lines the interior of the shift knob, such that the shift knob can be twisted upon shafts of varying diameters, and generally remain firmly upon the shaft 577 until twisted off.

Ultimately, in the typical driving simulation scenario depicted in FIG. 26C, comprised of a steering wheel, transmission shift knob, and floor pedal base with individually functioning pedals, where tactile sensation actuators are distributed throughout these disparate control input devices 570,575,580,585, and simultaneously within a seating unit 510 and a chest harness 520, or some subset thereof, the simulation user will be exposed to tactile sensations that help to convince his or her senses that the simulation is real. Furthermore, due to the substantially unified manner of operation these disparate tactile feedback devices, the driving simulation user will benefit from the illusion that these disparate devices are all attached to the same physical structure.

In FIG. 26D, the first person perspective open-body combat game, the central tactile feedback device is a vest-based tactile sensation generator 595. One very common control input device used for 1st person perspective combat games, and for most console games, is a hand-held game pad. FIG. 38A depicts a front view of an illustrative hand-held control input device. FIG. 38B is the back of the controller of FIG. 38A. Vibratory motors and/or solenoids can be attached to the hand-held game pad as depicted in FIGs. 83 and 84. In FIG. 38C, a vibratory tactile sensation generator 590 is attached to the back of the

APPENDIX A Host-Independent "AudioSense™" System Analysis Display Modes

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\_____CACULATED AudioSense results____/
```

This is the most common display. Most AudioSense files will use this display to help you calibrate AudioSense for any given game. This mode shows the total CALCULATED results of the BASS, MIDRANGE and TREBLE audio after being processed by AudioSense. All three audio bands share this one segment of all 20 LEDs, like a VU meter on a stereo.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪
\_____CACULATED AudioSense results____/
```

This display is just like the first mode, but displays a scanning DOT instead of a bar graph. This mode allows you to actually see the rapid fluctuations typical of digital audio signals. This display can be used to help dial in effective RISE RATE and DECAY RATE AudioSense settings, when necessary.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
◄ ▪ ◄ ▪ ◄ ▪ ◄ ▪ ◄ ▪ ► ▪ ► ▪ ► ▪ ► ▪ ► ▪
\___left mirror___/ \___right mirror__/
```

This display is just like the previous DOT mode, but displays two opposing mirrors of a scanning dot. This is the only LED mode that was not born out of necessity. I simply thought it might look cool during certain simulations, so here it is.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► - ► ► ► ► ► ► - ► ► ► ► ► ►
\_CAL BASS_/  \_CAL MID_/   \_CAL TREB_/
```

This mode divides the available LEDs into 3 individual segments, effectively creating three independent LED meters. Each segment shows a single processed audio band, allowing this mode to show you all three independent audio bands simultaneously. All three segments are CALCULATED, so they show the complete results of AudioSense digital signal processing in real time. However, with each segment made up of only 6 LEDs, the display is rather low in resolution.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\________CALCULATED BASS results_______/
```

This display shows the CALCULATED BASS results, after being processed by the BASS AudioSense parameters. This display will give you the best available view of the CALCULATED BASS audio results, as this mode displays the BASS results over all 20 LEDs.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\_____CALCULATED MIDRANGE results_____/
```

This display shows the CALCULATED MIDRANGE results, after being processed by the MIDRANGE AudioSense parameters. This display will give you the best available view of the CALCULATED MIDRANGE audio results, as this mode displays the MIDRANGE results over all 20 LEDs.

APPENDIX A

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________RAW MIDRANGE audio__________/
```

This display shows the RAW MIDRANGE audio signal as it is digitally sampled. This mode will give you the best available view of the RAW MIDRANGE audio activity as it is generated by any given game or simulation.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\____________RAW TREB audio____________/
```

This display shows the RAW TREBLE audio signal as it is digitally sampled. This mode will give you the best available view of the RAW TREBLE audio activity as it is generated by any given game or simulation.

Host-Dependent "intelliVIBE™" System Analysis Display Modes

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\_______main intelliVIBE signal_______/
```

This display mode will show the main intelliVIBE signal on all 20 LEDs. The main signal is known as ZONE 0, or as the device LEADER. The intelliVIBE main signal is unique in that it does not control any specific zone, but all other zones (1-8) will FOLLOW this signal unless they have been directly told not to do so. If intelliVIBE zones 1-8 are all doing their own thing, this display may be dead, even though activity is happening elsewhere.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► • ► • ► • ► • ► • ► • ► • ► • ► • ► •
\_______main intelliVIBE signal_______/
```

This display is just like the first mode, but displays a scanning DOT instead of a bar graph.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► - - ◄ ◄ ◄ ◄ ◄ ◄ ► ► ► ► ► ►
\_TFSU BACK_/   \_LEFT LEG_/ \_RIGHT LEG_/
```

This display mode shows the activity in all three zones of the TFSU.

LEDs 1-6 show the activity in the ZONE 1 TFSU BACK section.

LEDs 9-14 show the activity in the ZONE 2 TFSU LEFT LEG section.
LEDs 15-20 show the activity in the ZONE 3 TFSU RIGHT LEG section.

APPENDIX A

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\___________ZONE 1 TFSU BACK__________/
```

This display mode shows the activity on the ZONE 1 TFSU BACK section.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\_________ZONE 2 TFSU LEFT LEG________/
```

This display mode shows the activity on the ZONE 2 TFSU LEFT LEG section.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\_______ZONE 3 TFSU RIGHT LEG_________/
```

This display mode shows the activity on the ZONE 3 TFSU RIGHT LEG section.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________EXPANSION ZONE 4___________/
```

This display mode shows the activity on EXPANSION ZONE 4.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________EXPANSION ZONE 5___________/
```

This display mode shows the activity on EXPANSION ZONE 5.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________EXPANSION ZONE 6___________/
```

This display mode shows the activity on EXPANSION ZONE 6.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________EXPANSION ZONE 7___________/
```

This display mode shows the activity on EXPANSION ZONE 7.

LED DISPLAY MODES HELP DIAGRAM

```
1 2 3 4 5 6 7 8 9 0 1 2 3 4 5 6 7 8 9 20
► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ► ►
\__________EXPANSION ZONE 8___________/
```

where said first portion interfits with a back portion of a chair and said second portion interfits with a seat portion of a chair.

13. The apparatus of claim 11 wherein said flexible pad is affixed to a stationary seating system.

14. The apparatus of claim 11 wherein each actuator in said plurality of actuators is an electric motor having a shaft with an offset weight attached thereto.

15. The apparatus of claim 14 wherein each of said electric motors is enclosed in a housing.

16. The apparatus of claim 15 wherein each of said electric motors is embedded in said flexible pad and a covering material is affixed to a surface of the flexible pad where each of said electric motors is sealed within said flexible pad by said covering material.

17. The apparatus of claim 11 wherein each actuator in said plurality of actuators in independently activated.

18. The apparatus of claim 11 wherein said plurality of actuators are organized into groups and each of said groups is independently activated.

19. The apparatus of claim 11 wherein said flexible pad is substantially shaped as a motorcycle seat.

20. The apparatus of claim 1 wherein said plurality of actuators are activated as a unified whole.

21. The apparatus of claim 11 wherein said plurality of actuators are activated as a unified whole.

22. The apparatus of claim 12 wherein said control circuit comprises:
an audio signal processor for processing said audio signal and generating a processed signal; and
a control signal generator, coupled to said audio signal processor, for generating, in response to said processed signal, said control signal.

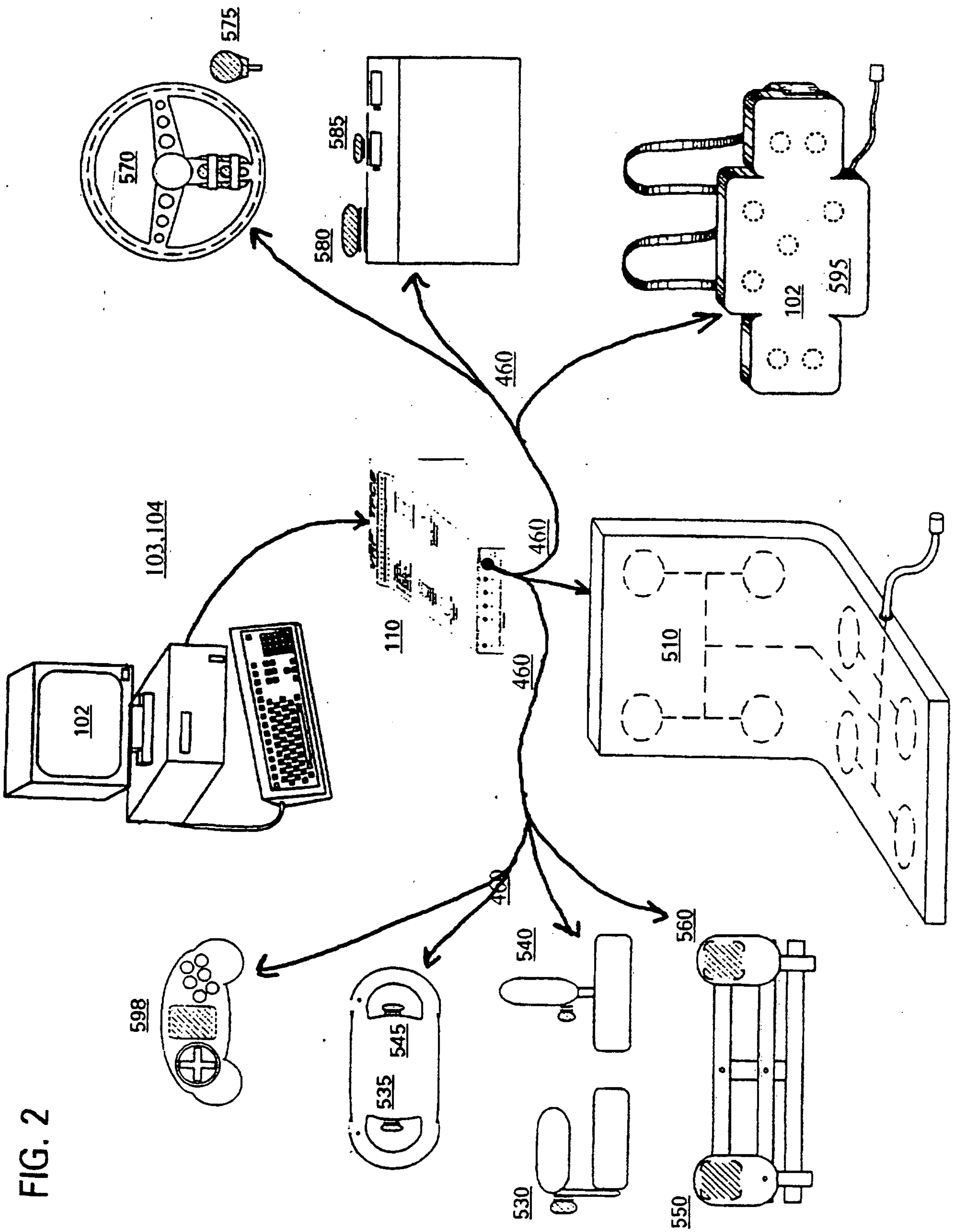
23. The apparatus of claim 22 wherein said audio signal processor comprises:
an analog pre-processing section; and
a digital post-processing section.

24. The apparatus of claim 23 wherein said digital post-processing section comprises:
a reconfigurable algorithm that can mathematically manipulate the digitized audio signal based upon reprogrammable parameters.

25. The apparatus of claim 23 wherein said analog pre-processing section comprises:
frequency filters to separate frequency components from the audio signal, whereupon each frequency so separated is converted into digital data via an ADC.

26. Apparatus for receiving a signal from a host computer for generating a control signal for a plurality of tactile sensation generators comprising:
a processor for processing said signal from the host computer to produce a master control signal, where said master control signal is used to derive one or more control signals to activate the tactile sensation generators.

27. The apparatus of claim 1, wherein one of said tactile sensation generators is a shift knob.



575
570
585
580
595
102
460
460
103,104
110
460
510
102
460
540
560
598
545
535
530
550

FIG. 2

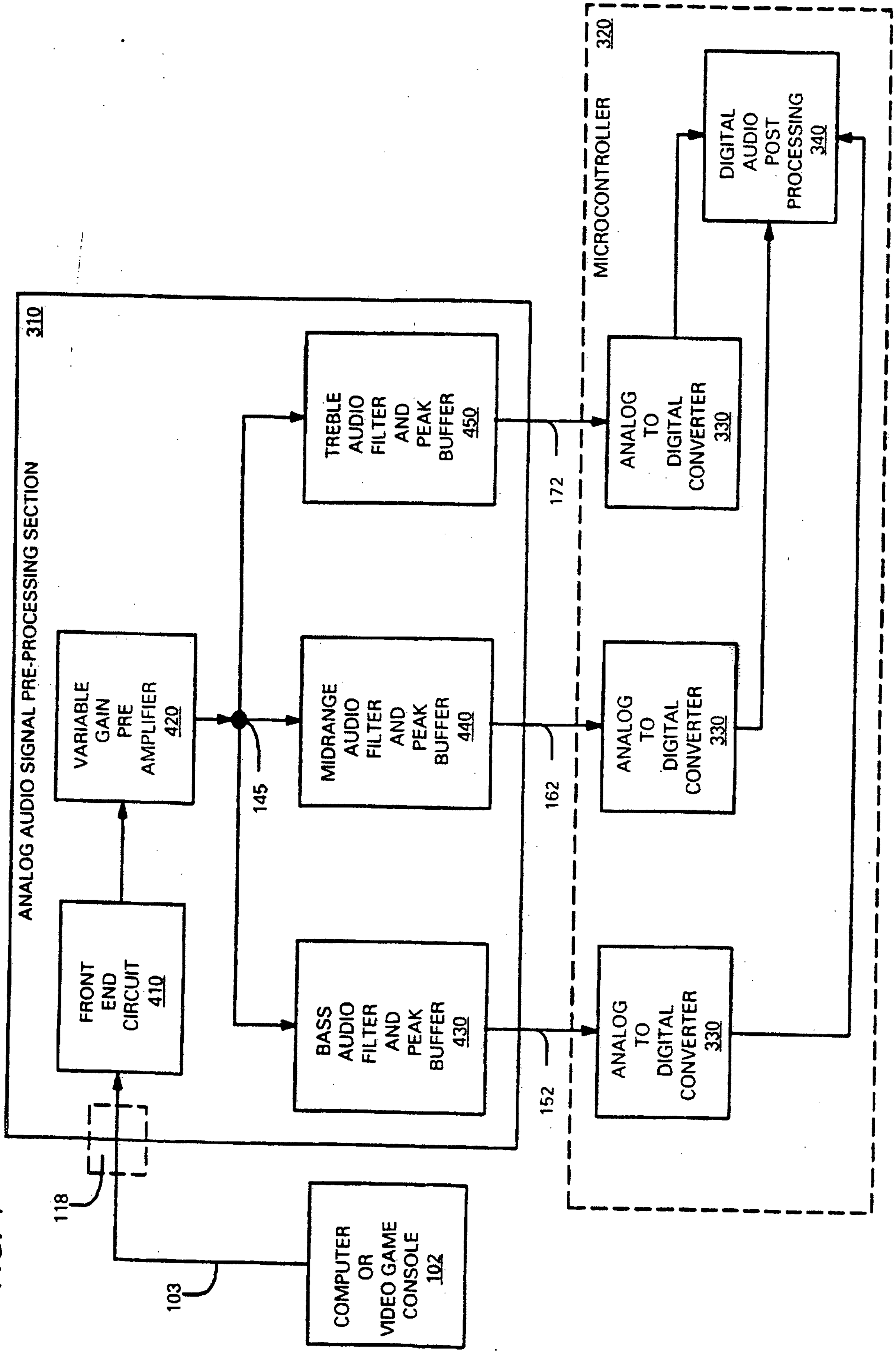

ANALOG AUDIO SIGNAL PRE-PROCESSING SECTION
310
FRONT END CIRCUIT 410
VARIABLE GAIN PRE AMPLIFIER 420
145
BASS AUDIO FILTER AND PEAK BUFFER 430
MIDRANGE AUDIO FILTER AND PEAK BUFFER 440
TREBLE AUDIO FILTER AND PEAK BUFFER 450
152
162
172
MICROCONTROLLER
320
ANALOG TO DIGITAL CONVERTER 330
ANALOG TO DIGITAL CONVERTER 330
ANALOG TO DIGITAL CONVERTER 330
DIGITAL AUDIO POST PROCESSING 340
118
103
COMPUTER OR VIDEO GAME CONSOLE 102

FIG. 4

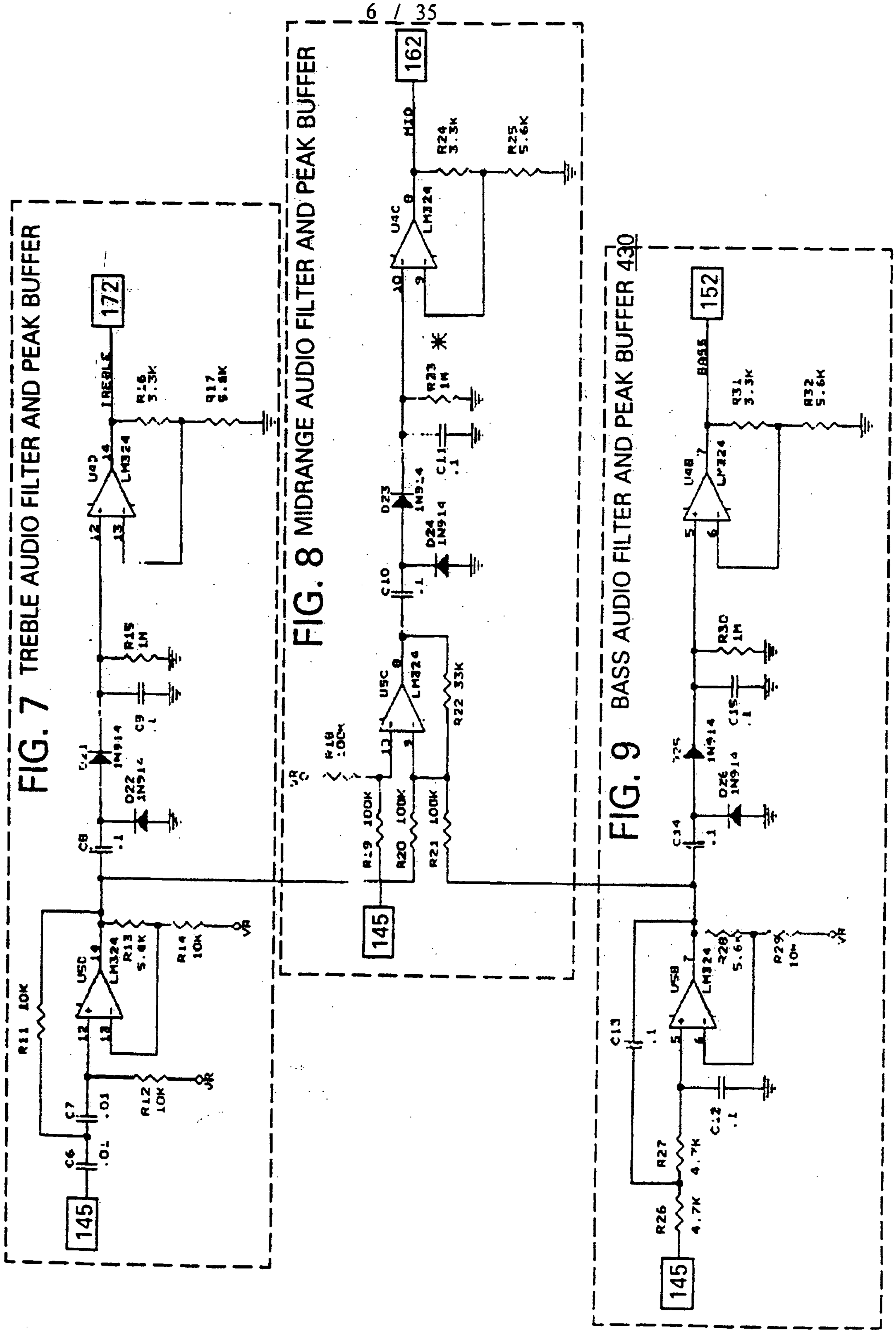


FIG. 7 TREBLE AUDIO FILTER AND PEAK BUFFER

FIG. 8 MIDRANGE AUDIO FILTER AND PEAK BUFFER

FIG. 9 BASS AUDIO FILTER AND PEAK BUFFER 430

FIG. 12

BASS AUDIO ANALYSIS 1120

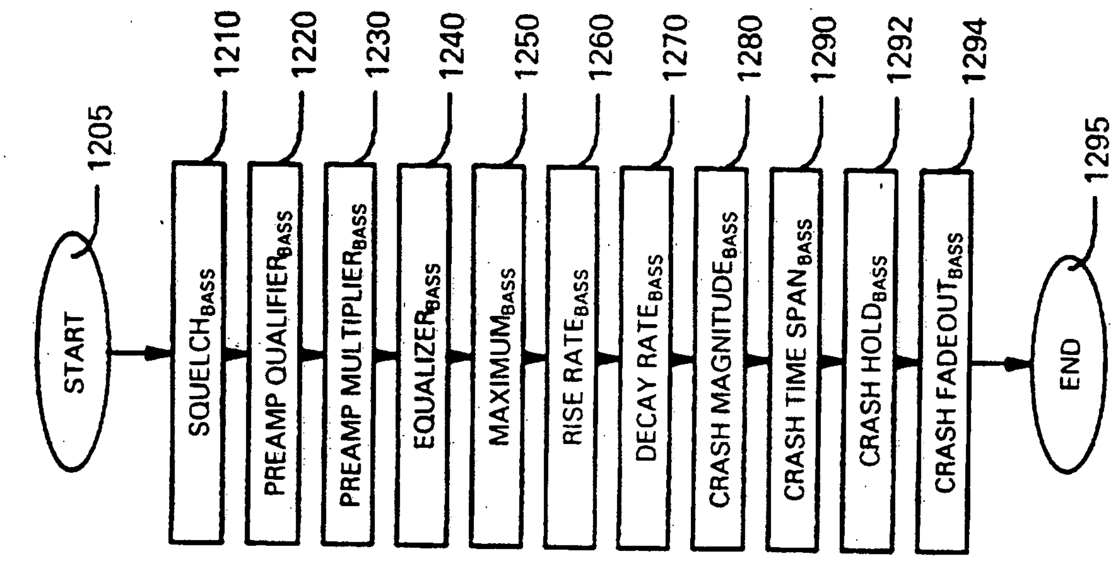


FIG. 11

DIGITAL AUDIO POST-PROCESSING 1065

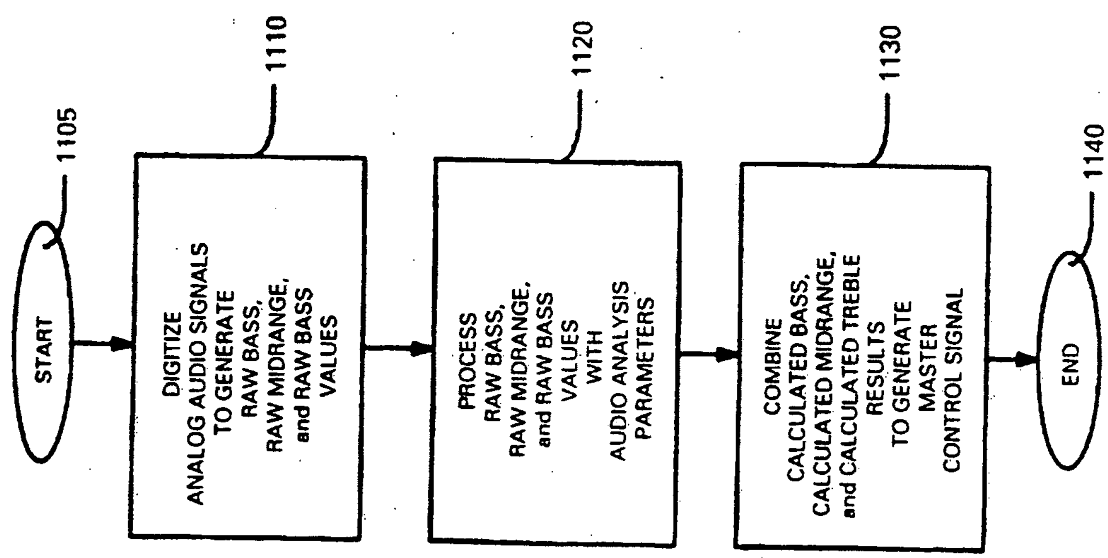


FIG. 15

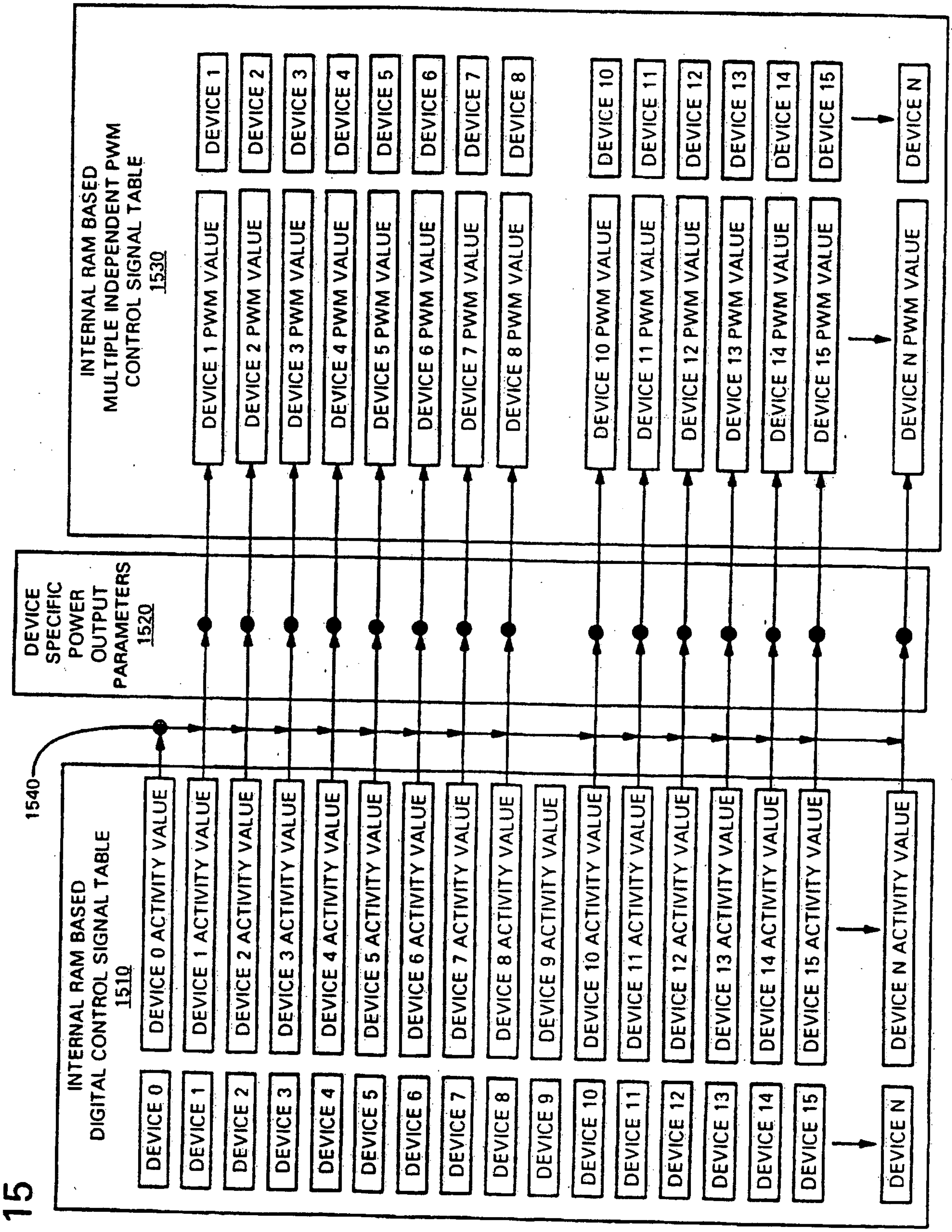

INTERNAL RAM BASED
DIGITAL CONTROL SIGNAL TABLE
1510
DEVICE 0
DEVICE 1
DEVICE 2
DEVICE 3
DEVICE 4
DEVICE 5
DEVICE 6
DEVICE 7
DEVICE 8
DEVICE 9
DEVICE 10
DEVICE 11
DEVICE 12
DEVICE 13
DEVICE 14
DEVICE 15
DEVICE N
DEVICE 0 ACTIVITY VALUE
DEVICE 1 ACTIVITY VALUE
DEVICE 2 ACTIVITY VALUE
DEVICE 3 ACTIVITY VALUE
DEVICE 4 ACTIVITY VALUE
DEVICE 5 ACTIVITY VALUE
DEVICE 6 ACTIVITY VALUE
DEVICE 7 ACTIVITY VALUE
DEVICE 8 ACTIVITY VALUE
DEVICE 9 ACTIVITY VALUE
DEVICE 10 ACTIVITY VALUE
DEVICE 11 ACTIVITY VALUE
DEVICE 12 ACTIVITY VALUE
DEVICE 13 ACTIVITY VALUE
DEVICE 14 ACTIVITY VALUE
DEVICE 15 ACTIVITY VALUE
DEVICE N ACTIVITY VALUE
1540
DEVICE SPECIFIC POWER OUTPUT PARAMETERS
1520
INTERNAL RAM BASED
MULTIPLE INDEPENDENT PWM
CONTROL SIGNAL TABLE
1530
DEVICE 1 PWM VALUE
DEVICE 2 PWM VALUE
DEVICE 3 PWM VALUE
DEVICE 4 PWM VALUE
DEVICE 5 PWM VALUE
DEVICE 6 PWM VALUE
DEVICE 7 PWM VALUE
DEVICE 8 PWM VALUE
DEVICE 10 PWM VALUE
DEVICE 11 PWM VALUE
DEVICE 12 PWM VALUE
DEVICE 13 PWM VALUE
DEVICE 14 PWM VALUE
DEVICE 15 PWM VALUE
DEVICE N PWM VALUE
DEVICE 1
DEVICE 2
DEVICE 3
DEVICE 4
DEVICE 5
DEVICE 6
DEVICE 7
DEVICE 8
DEVICE 10
DEVICE 11
DEVICE 12
DEVICE 13
DEVICE 14
DEVICE 15
DEVICE N

FIG. 17

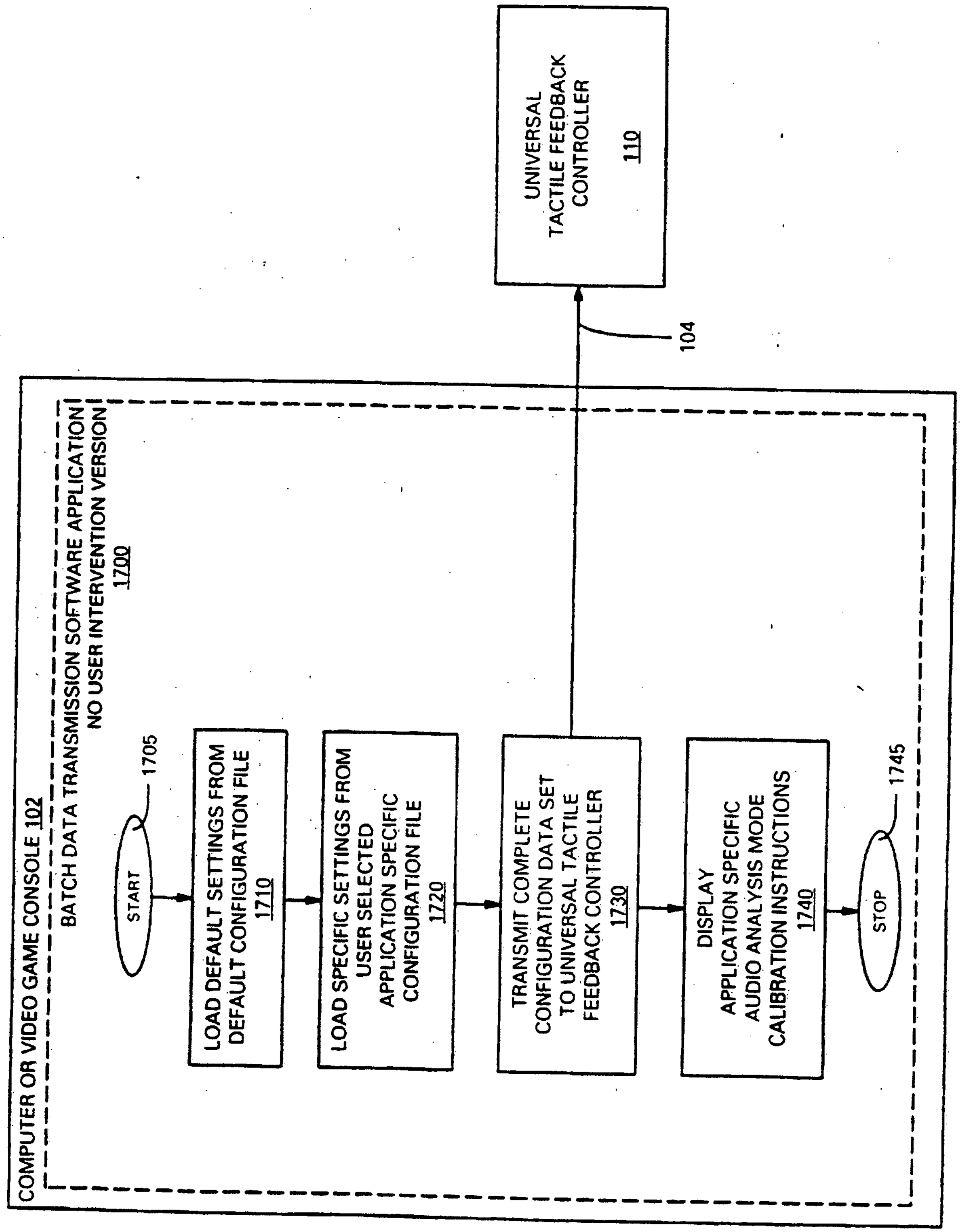

COMPUTER OR VIDEO GAME CONSOLE 102
BATCH DATA TRANSMISSION SOFTWARE APPLICATION
NO USER INTERVENTION VERSION
1700
START
1705
LOAD DEFAULT SETTINGS FROM DEFAULT CONFIGURATION FILE
1710
LOAD SPECIFIC SETTINGS FROM USER SELECTED APPLICATION SPECIFIC CONFIGURATION FILE
1720
TRANSMIT COMPLETE CONFIGURATION DATA SET TO UNIVERSAL TACTILE FEEDBACK CONTROLLER
1730
DISPLAY APPLICATION SPECIFIC AUDIO ANALYSIS MODE CALIBRATION INSTRUCTIONS
1740
STOP
1745
104
UNIVERSAL TACTILE FEEDBACK CONTROLLER
110

FIG. 19 HOST INDEPENDENT AUDIO-ANALYSIS CALIBRATION ROUTINE 1900

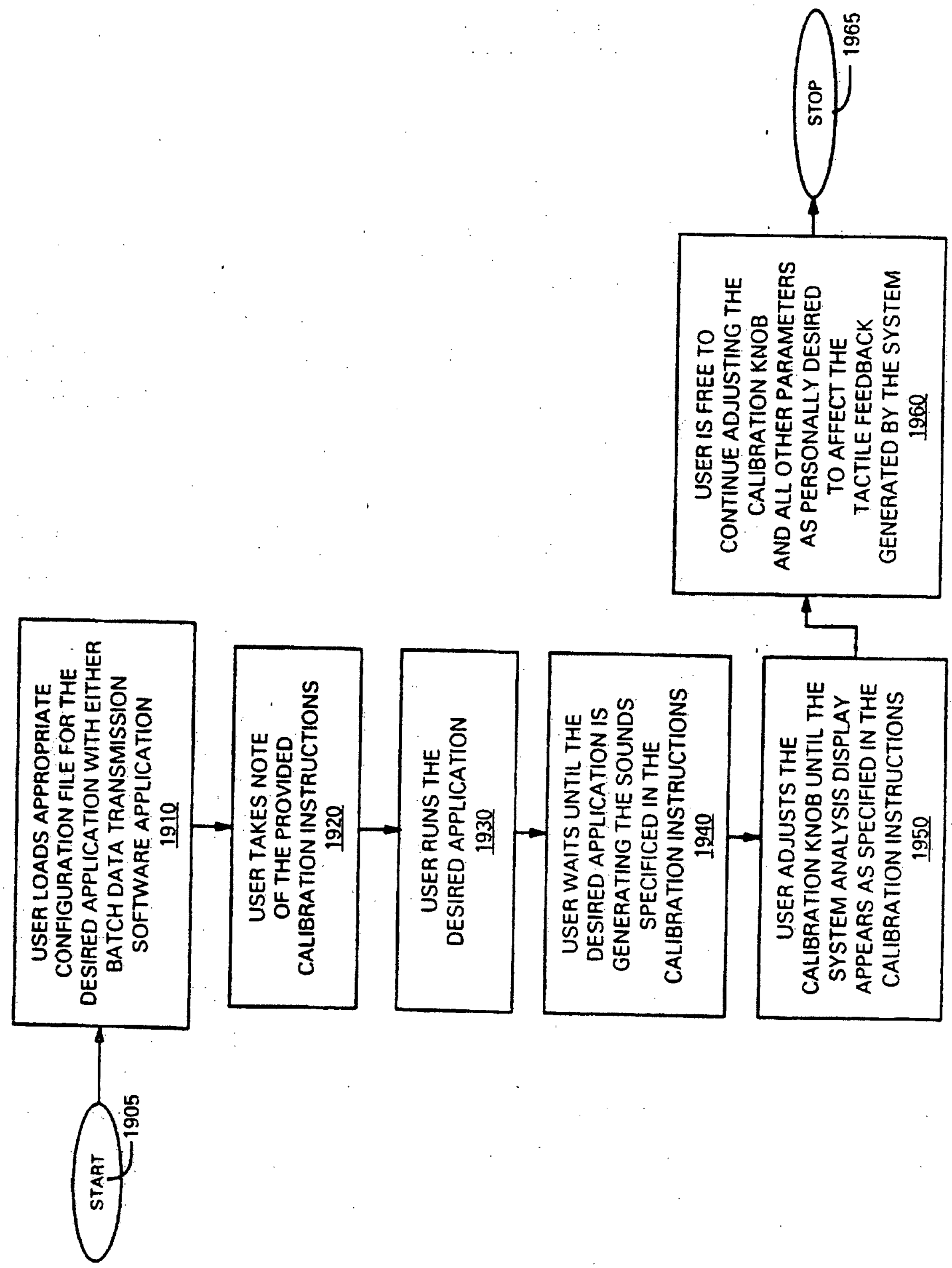


FIG. 22

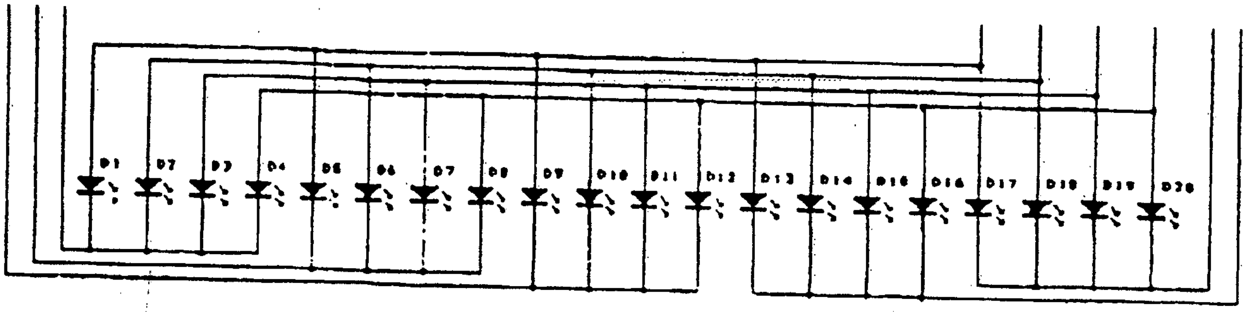


FIG. 23

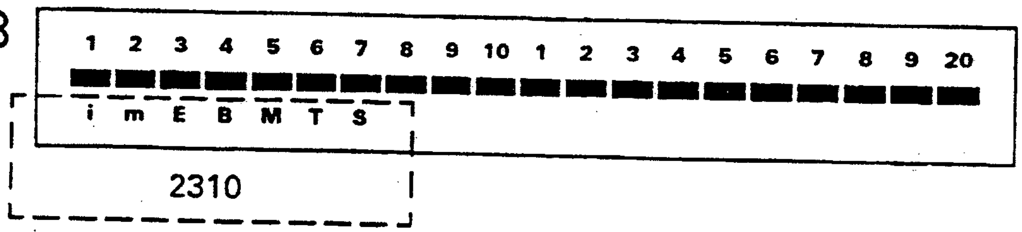
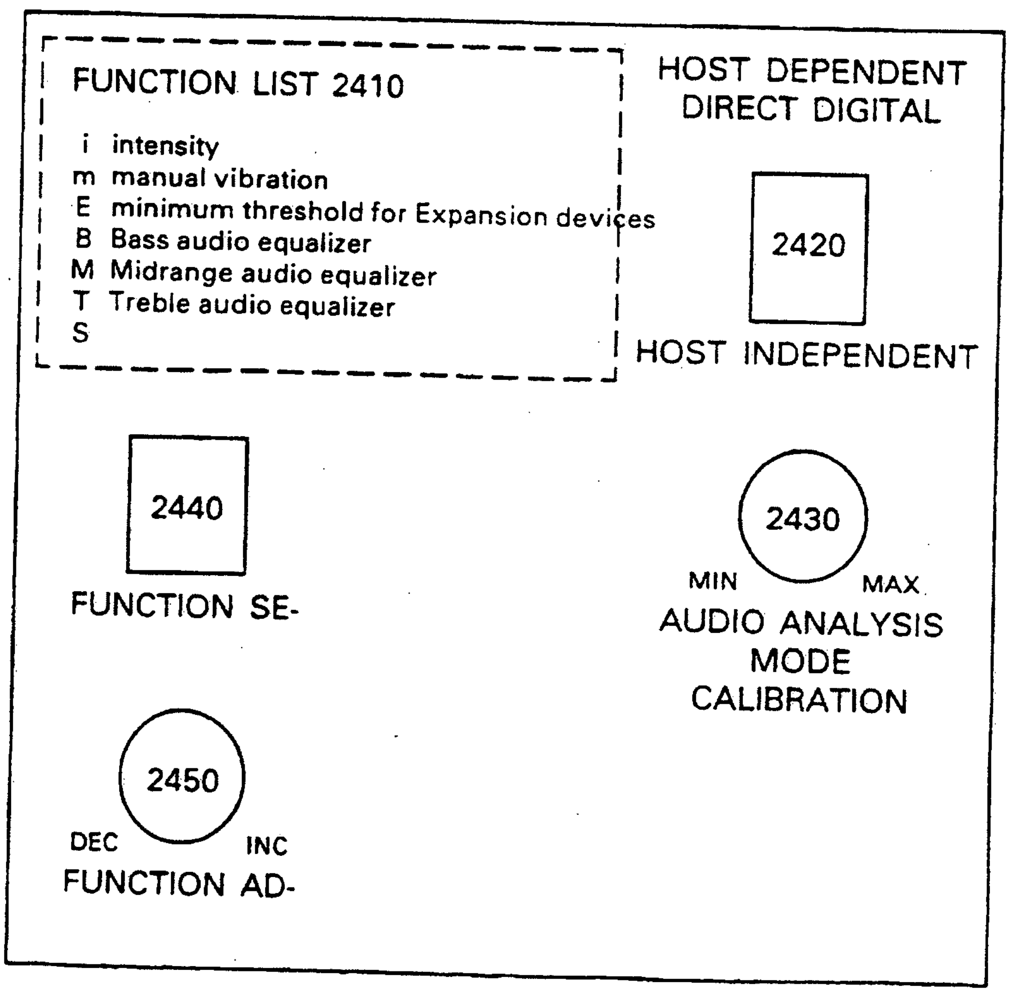


FIG. 24



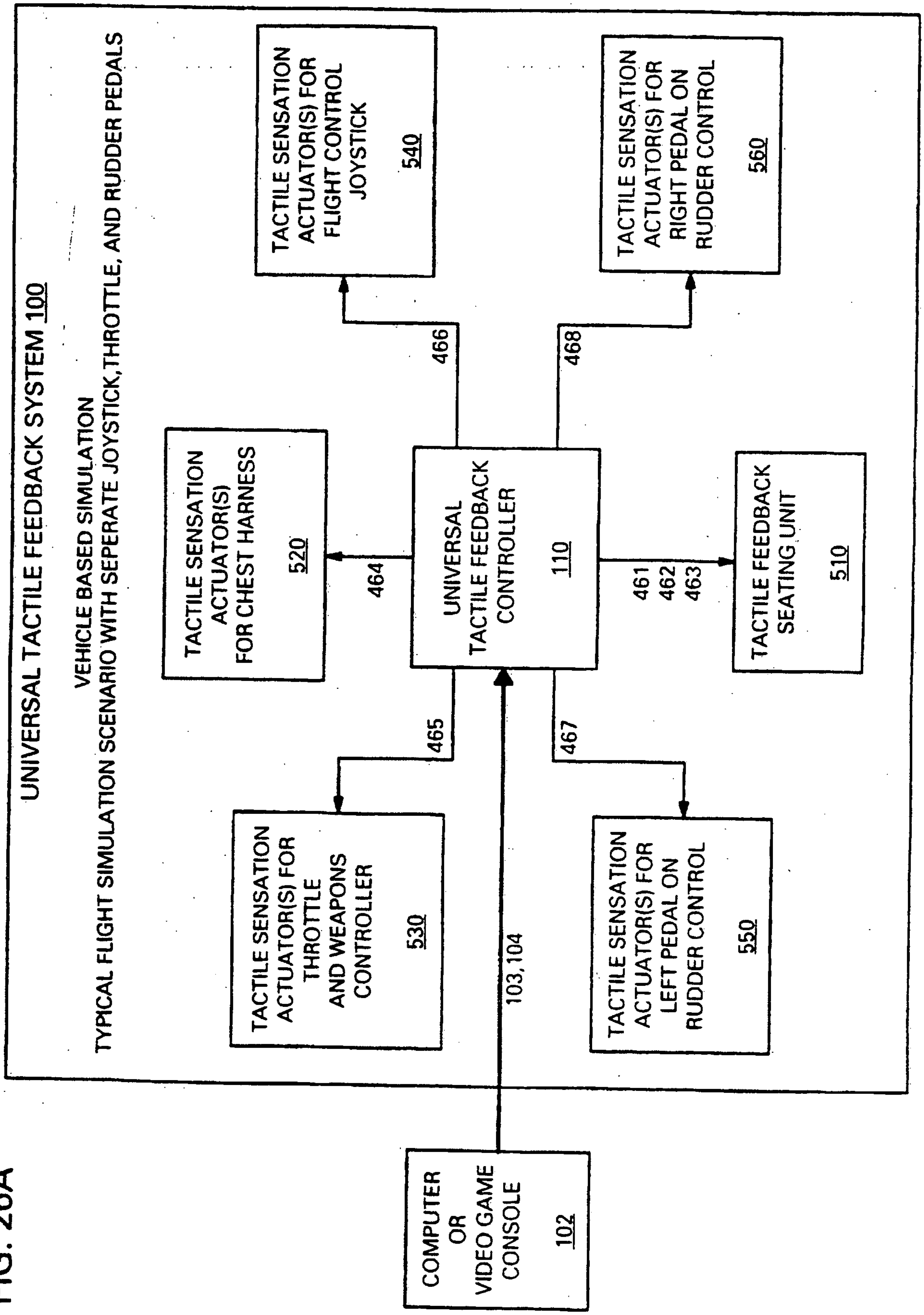

UNIVERSAL TACTILE FEEDBACK SYSTEM 100
VEHICLE BASED SIMULATION
TYPICAL FLIGHT SIMULATION SCENARIO WITH SEPERATE JOYSTICK, THROTTLE, AND RUDDER PEDALS
TACTILE SENSATION ACTUATOR(S) FOR FLIGHT CONTROL JOYSTICK 540
TACTILE SENSATION ACTUATOR(S) FOR RIGHT PEDAL ON RUDDER CONTROL 560
TACTILE SENSATION ACTUATOR(S) FOR CHEST HARNESS 520
UNIVERSAL TACTILE FEEDBACK CONTROLLER 110
TACTILE FEEDBACK SEATING UNIT 510
TACTILE SENSATION ACTUATOR(S) FOR THROTTLE AND WEAPONS CONTROLLER 530
TACTILE SENSATION ACTUATOR(S) FOR LEFT PEDAL ON RUDDER CONTROL 550
COMPUTER OR VIDEO GAME CONSOLE 102
466
468
464
461
462
463
465
467
103,104

FIG. 26A

FIG. 26C

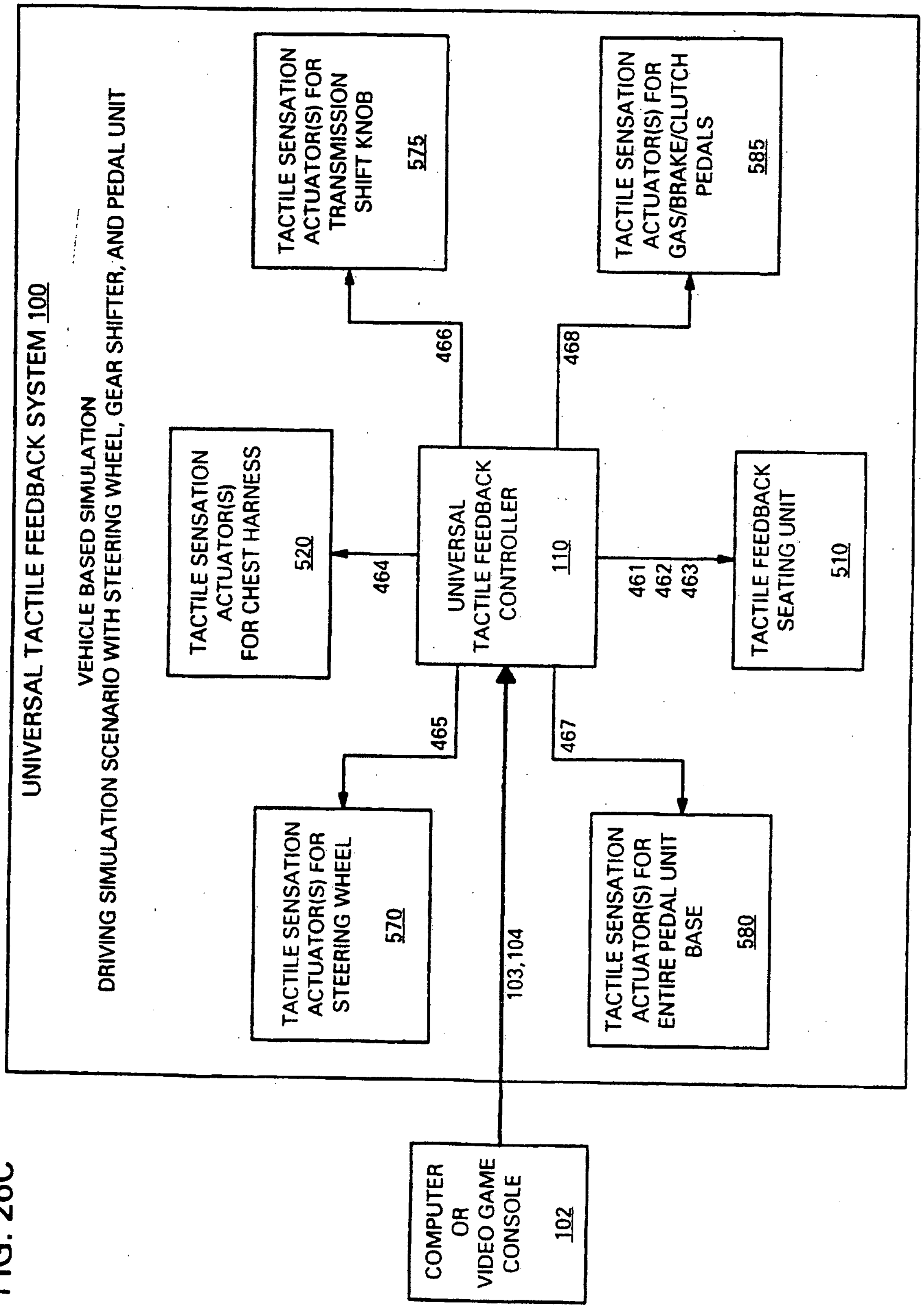
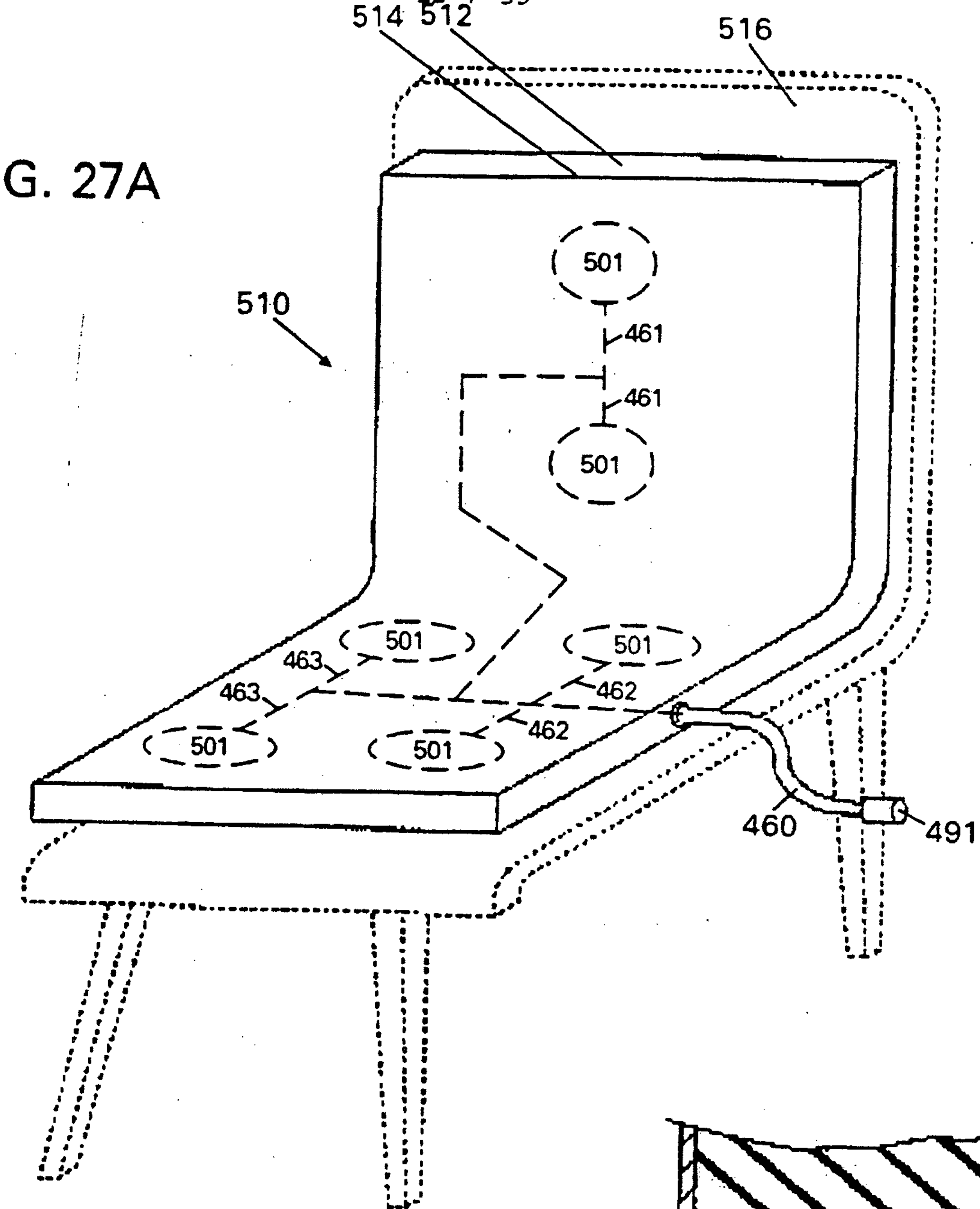

UNIVERSAL TACTILE FEEDBACK SYSTEM 100
VEHICLE BASED SIMULATION
DRIVING SIMULATION SCENARIO WITH STEERING WHEEL, GEAR SHIFTER, AND PEDAL UNIT
TACTILE SENSATION ACTUATOR(S) FOR TRANSMISSION SHIFT KNOB 575
TACTILE SENSATION ACTUATOR(S) FOR GAS/BRAKE/CLUTCH PEDALS 585
466
468
TACTILE SENSATION ACTUATOR(S) FOR CHEST HARNESS 520
464
UNIVERSAL TACTILE FEEDBACK CONTROLLER 110
461
462
463
TACTILE FEEDBACK SEATING UNIT 510
465
467
TACTILE SENSATION ACTUATOR(S) FOR STEERING WHEEL 570
103,104
TACTILE SENSATION ACTUATOR(S) FOR ENTIRE PEDAL UNIT BASE 580
COMPUTER OR VIDEO GAME CONSOLE 102

FIG. 27A



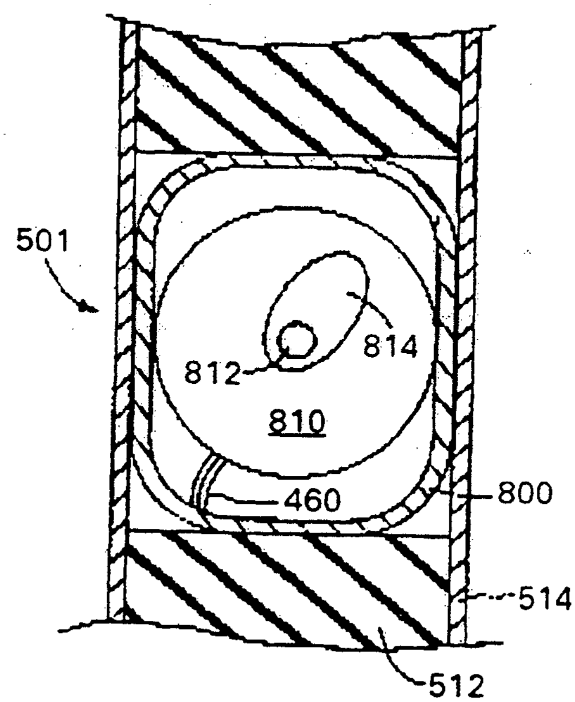


FIG. 27B

FIG. 28A

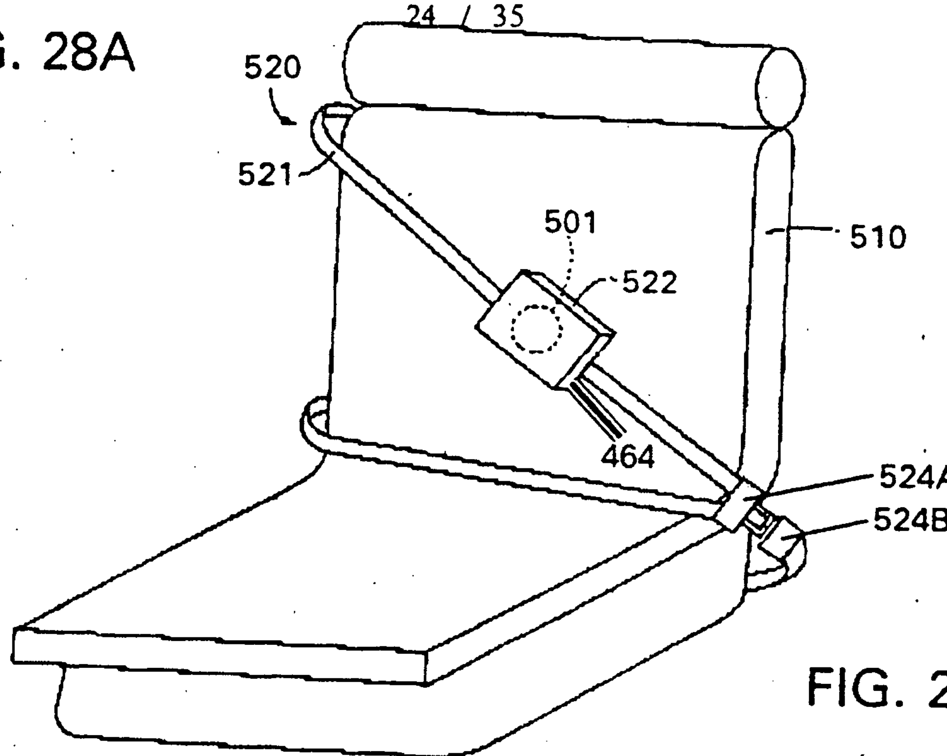


FIG. 28B

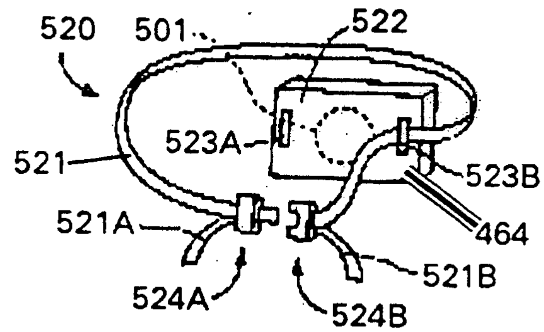
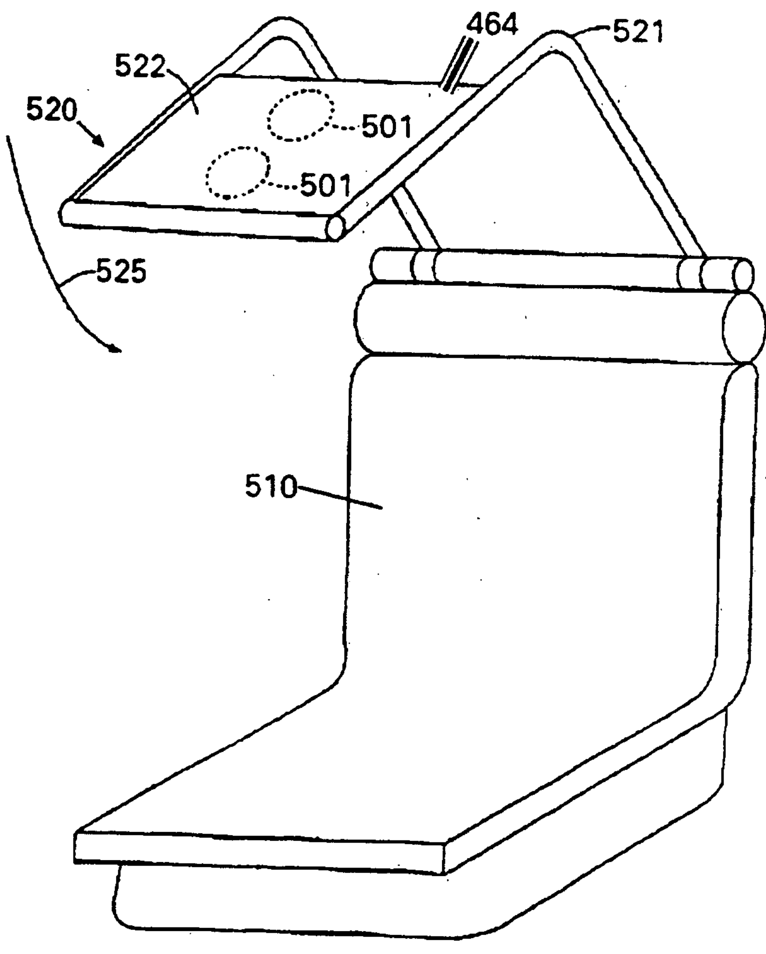


FIG. 28C



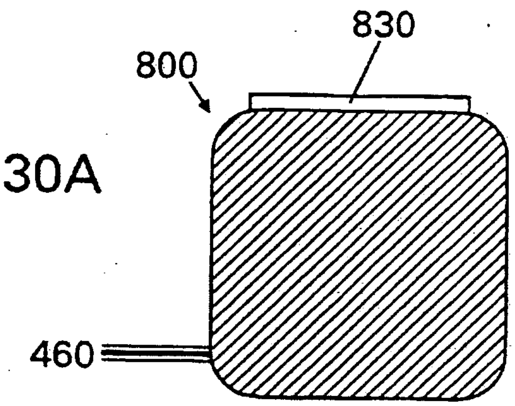


FIG. 30A

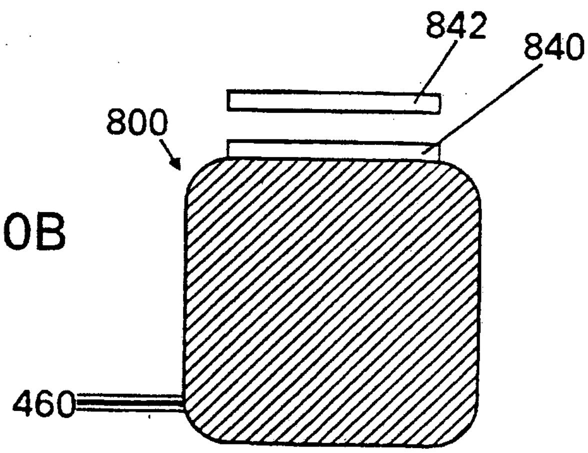


FIG. 30B

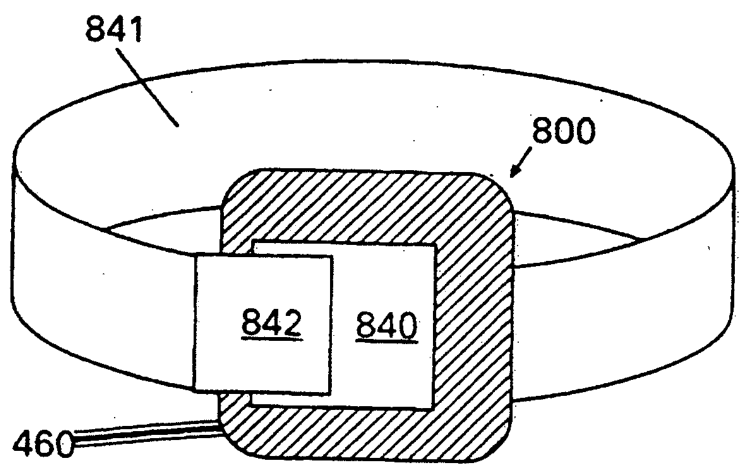


FIG. 30C

FIG. 32A

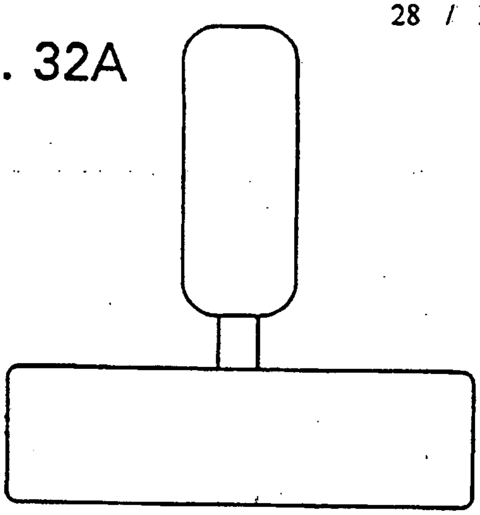


FIG. 32B

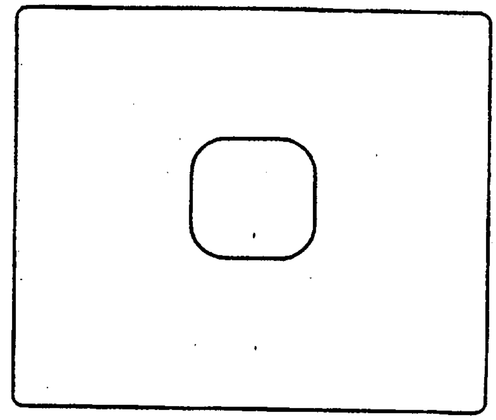


FIG. 32C

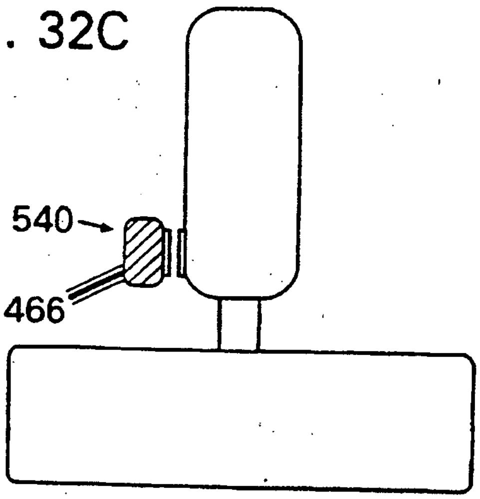


FIG. 32D

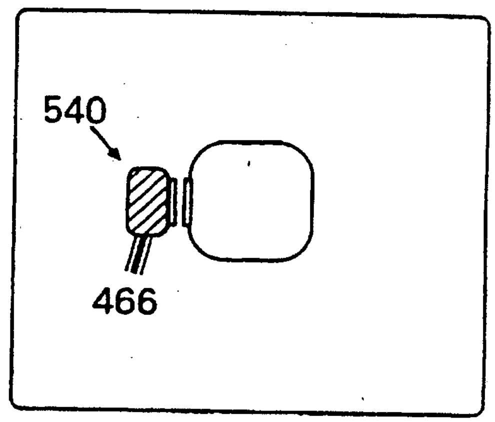


FIG. 32E

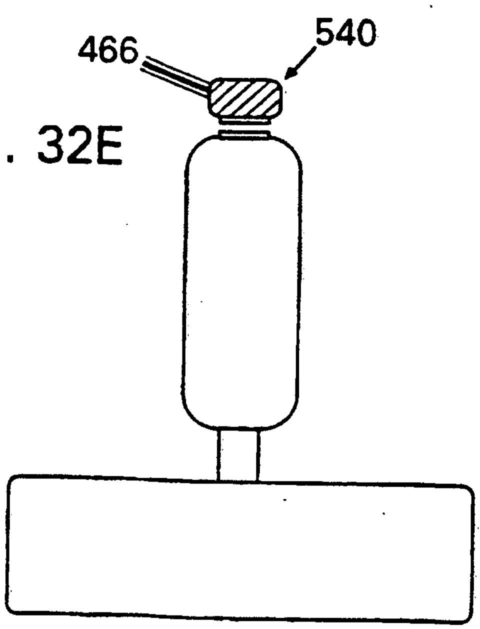
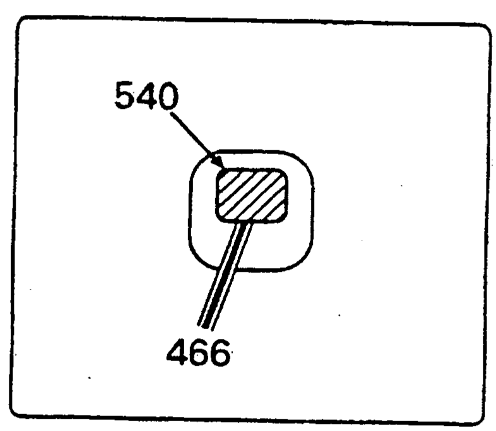


FIG. 32F



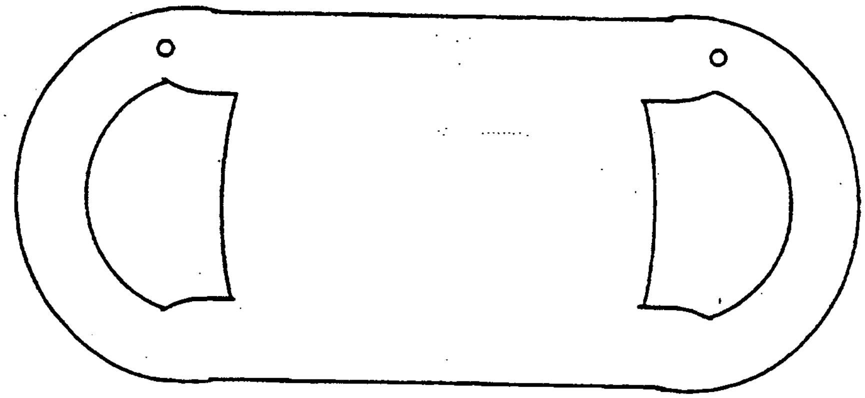


FIG. 34A

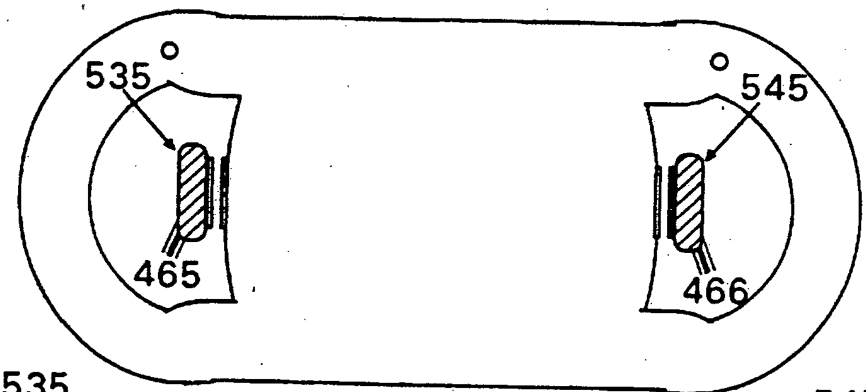


FIG. 34B

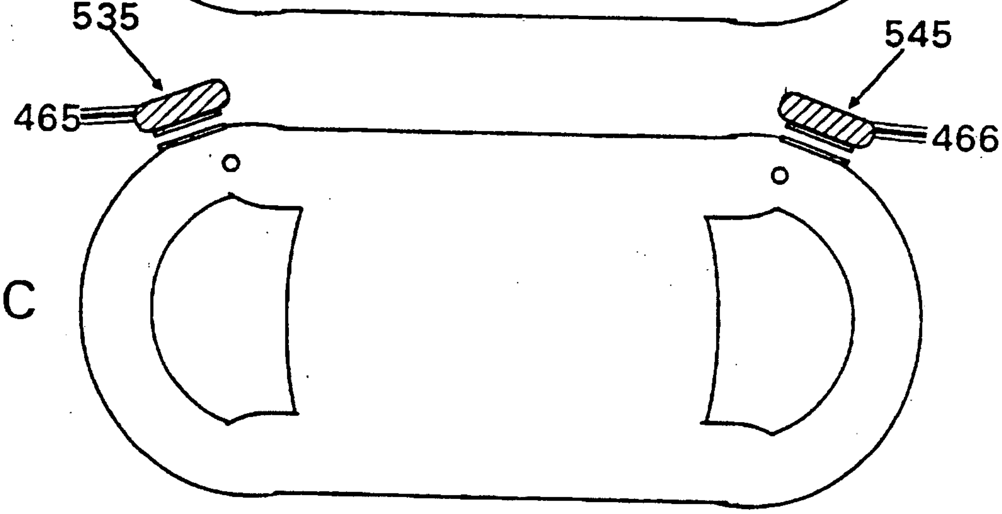


FIG. 34C

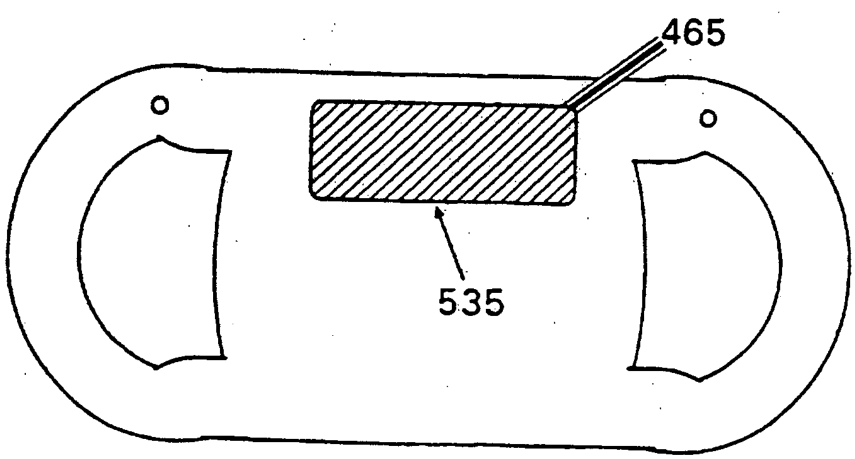


FIG. 34D

FIG. 36A

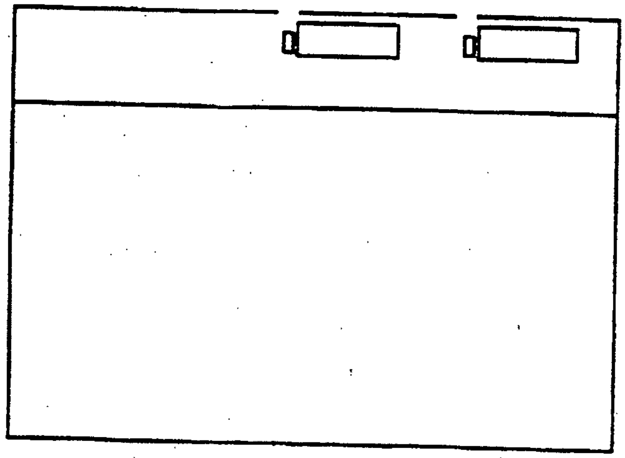
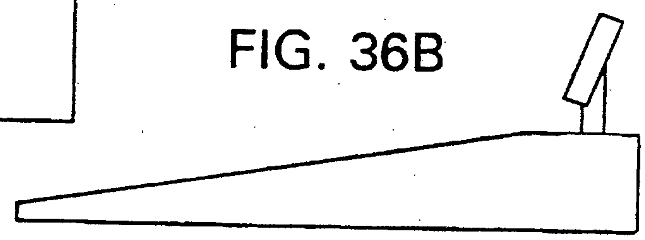


FIG. 36B



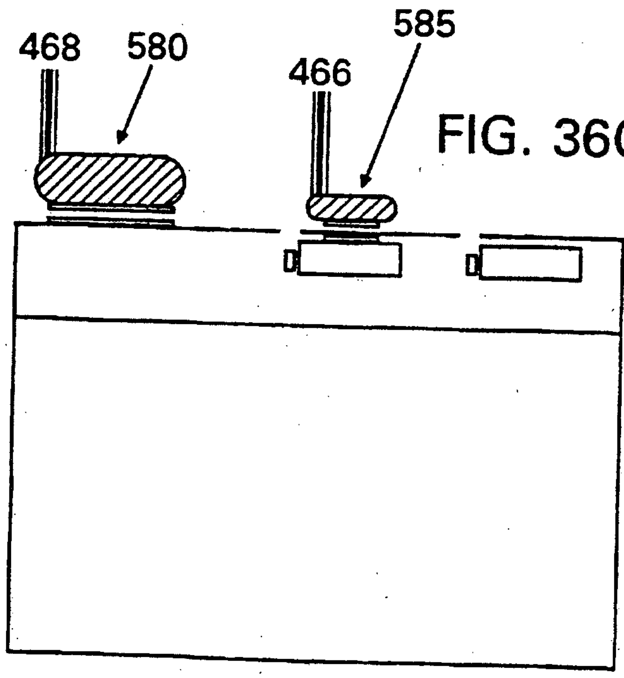


FIG. 36C

FIG. 36D

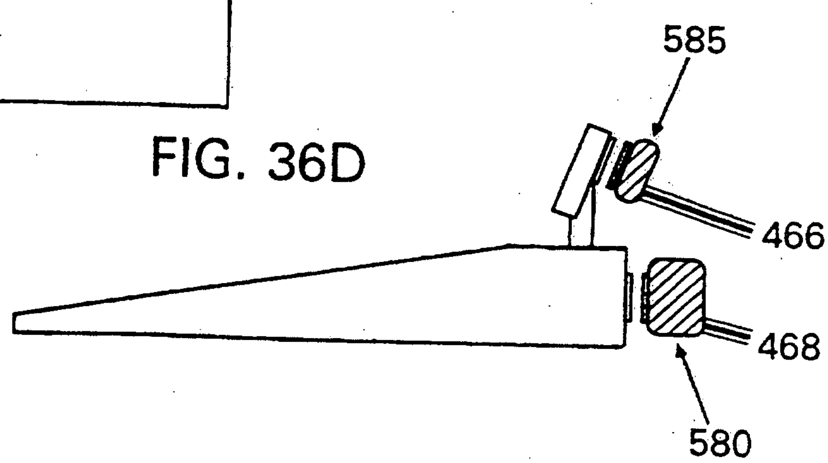


FIG. 38A

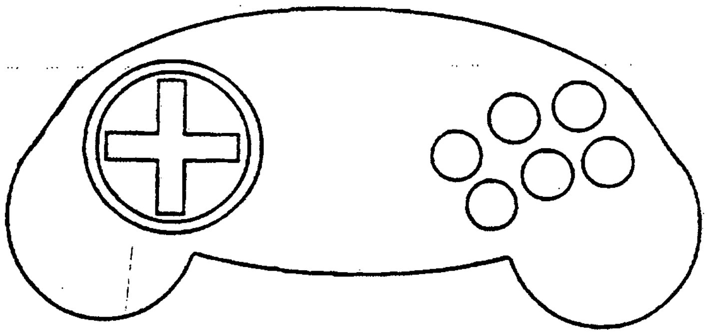


FIG. 38B

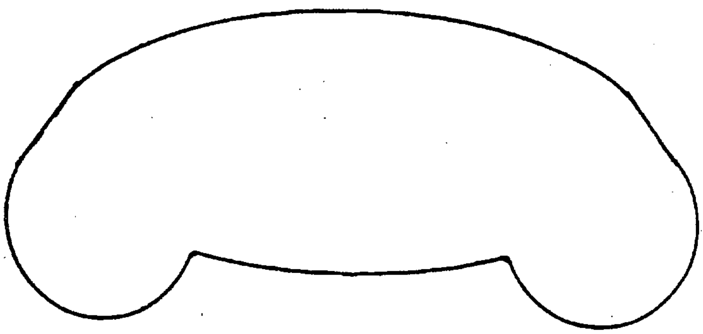


FIG. 38C

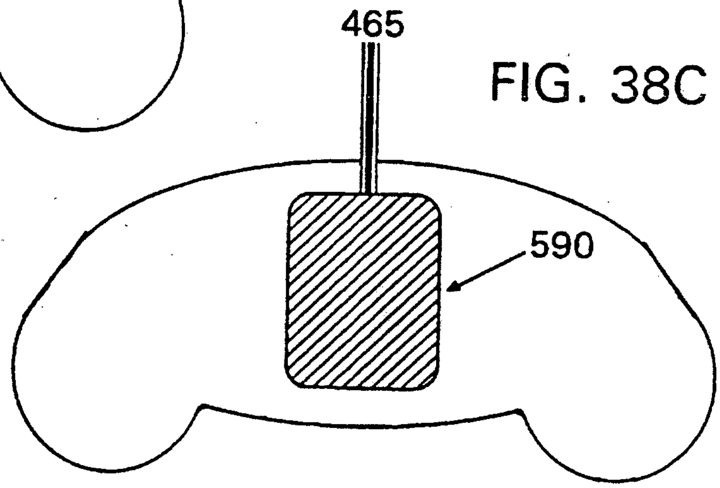
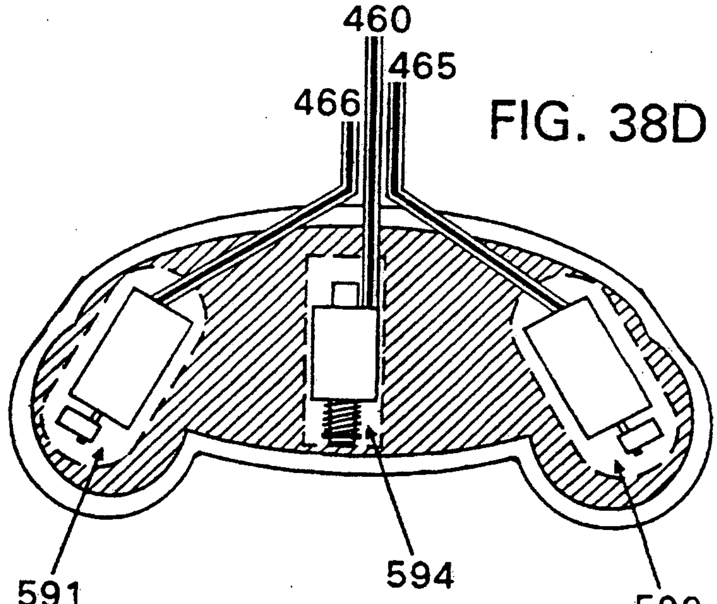


FIG. 38D



INTERNATIONAL SEARCH REPORT

International application No.
PCT/US98/19905

A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) :A63F 9/22
US CL :463/30, 47; 273/148B
According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 463/30, 47; 273/148B; 434/114

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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X,P	US 5,669,818 A (THORNER et al.) 23 September 1997, see entire document.	1-26
Y	US 5,299,810 A (PIERCE et al.) 05 April 1994, see entire document.	1-26
Y	US 5,203,563 A (LOPER, III) 20 April, 1993, see entire document.	4-6, 14-16
Y	US 4,771,344 (FALLACARO et al) 13 September 1988, see entire document.	1-26
Y	US 4,484,191 A (VAVRA) 20 November 1984, see entire document.	1-26
Y	US 3,902,687 A (HIGHTOWER) 02 September 1975, see entire document.	4-8 and 14-18

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Date of the actual completion of the international search 14 MARCH 1999	Date of mailing of the international search report 02 APR 1999
Name and mailing address of the ISA/US Commissioner of Patents and Trademarks Box PCT Washington, D.C. 20231	Authorized officer JAMES SCHAAF Sheila Veney Paralegal Specialist

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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : **A63F 9/22**	A3	(11) International Publication Number: **WO 99/17850** (43) International Publication Date: 15 April 1999 (15.04.99)

(21) International Application Number: PCT/US98/19905

(22) International Filing Date: 23 September 1998 (23.09.98)

(30) Priority Data:
08/935,762 23 September 1997 (23.09.97) US

(71)(72) Applicants and Inventors: THORNER, Craig [US/US]; 16 Nantucket Court, Howell, NJ 07731 (US). NEILMAN, Paul [US/US]; 1240 Rhus Street, San Mateo, CA 94402 (US).

(74) Common Representative: THORNER, Craig; 16 Nantucket Court, Howell, NJ 07731 (US).

(81) Designated States: CA, JP, European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE).

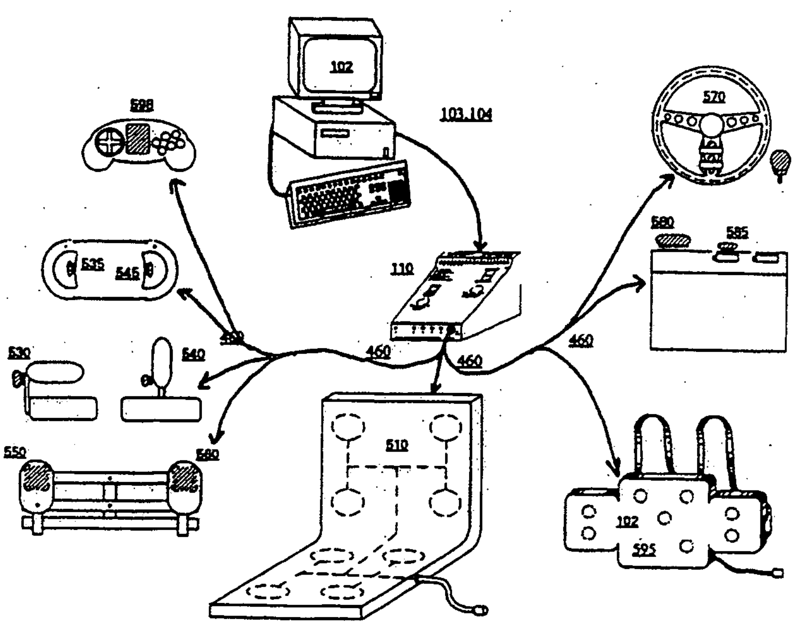
Published
With international search report.

(88) Date of publication of the international search report: 17 June 1999 (17.06.99)

(54) Title: A UNIVERSAL TACTILE FEEDBACK SYSTEM FOR COMPUTER VIDEO GAMES AND SIMULATIONS

(57) Abstract

A universal tactile feedback system for comptuer and video game systems which provides real time tactile feedback. The system includes a microcontroller based circuit that can operate in either a host-independent or a host-dependent mode. The host-independent mode is responsive to an audio signal which is typically generated by a computer while it is executing a game. The digital post-processing utilizes an algorithm with reprogrammable parameters that can be uniquely set for any given game or simulation. After the audio signal is processed, the results are used to generate multiple independent control signals for multiple independent tactile sensation generators (510, 520, 530, 540, 535, 545, 550, 560, 570, 575, 585, 595 and 598). Alternatively, the host-dependent mode is directly responsive to control commands generated by a computer while it is executing a game. All reconfigurable parameters are reprogrammable in real time by sending a communication to the controller (110) via any typical digital I/O port. The system's tactile sensation generators include independent groups of one or more actuators that are embedded within or attached to various devices.



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Y	US 5,203,563 A (LOPER, III) 20 April, 1993, see entire document.	4-6, 14-16
Y	US 4,771,344 (FALLACARO et al) 13 September 1988, see entire document.	1-26
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